THE DESIGN AND ANALYSIS OF LARGE DISPLAY GROUPWARE APPLICATIONS

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THE DESIGN AND ANALYSIS OF LARGE DISPLAY GROUPWARE APPLICATIONS

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I cannot pick just one. For Joe, Khai, and my family,
in gratitude for the love and support they have given me

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'for·tu·nate: 1. bringing some good thing not foreseen as certain; **2**. receiving some unexpected good.

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SUMMARY

Despite the proliferation of large-scale displays in the workplace, creating groupware applications that take advantage of their potential for collaboration and communication remains a challenge. Interactions with large displays yield user experiences that are quite different from interaction with conventional desktop groupware. Thus, unique hurdles exist for designing and deploying large display groupware applications (LDGAs) that are useful and adopted into actual work practice

In this dissertation we uncover and address some of the primary challenges for large display groupware applications though the design, development, deployment and evaluation of LDGA systems, as well as through the analysis of existing deployed LDGA systems. We present novel LDGA designs that address the issues of information awareness and informal communication through the use of large shared displays in workplaces and describe the findings from evaluations of their deployments. We then discuss a broad study of several existing LDGAs that we conducted and a framework of adoption challenges that we subsequently derived. We describe the application of this framework to the design a large display groupware application for supporting lightweight communication among workgroup members.

We also present a field study of the use of LDGAs within the context of multi-display environments, looking specifically at the display technologies used by NASA scientists and engineers for the Mars Exploration Rover (MER) missions. This work uncovers how the display environment provides flexible support for science tasks as collaboration styles and mission goals evolve. We offer suggestions for how LDGAs

should be designed and evaluated in light of our findings regarding the roles of LDGAs within an ecology of displays. Finally, we use the results of this evaluation as input for further refining our framework for LDGA adoption challenges.

CHAPTER 1

INTRODUCTION TO LARGE DISPLAY GROUPWARE

1.1 Motivation

The importance of information awareness, communication, and collaboration among workgroup members is unquestionable, as evidenced by workgroups' ever-increasing use of Computer Supported Cooperative Work (CSCW) tools to support such interaction needs in workgroups. Such tools have traditionally focused on the use of personal objects within the user's personal space, with most groupware systems being developed for desktop computers or personal mobile devices.

The increasing ubiquity of large display technologies has helped to open the design space of groupware beyond single-user interactions. Large displays are a particularly appealing platform for CSCW tools because of various characteristics that support group use and interaction; they are highly visible and can be easily viewed by multiple users simultaneously. Their physical size offers the potential for users to interact simultaneously on a shared physical workspace. In addition, as previous studies by Whittaker *et al.* have found that significant amounts of work take place outside of the personal workspace [Whittaker, Frohlich & Daly-Jones 1994], group displays located in shared workspace present the opportunity to further extend the utility of groupware for supporting collaboration and interaction. Display systems situated such that they can be easily viewed or appropriated bear an aspect of locational opportunism that can be leveraged for increasing awareness or supplementing work interactions provided that the situation and functionality of the display are a good match for the types of activities appropriate for the location.

Despite the proliferation of large-scale displays in the workplace, creating groupware applications that take advantage of their potential for collaboration and communication remains challenging. Interactions with large displays yield user experiences that are quite different from interaction with conventional desktop groupware. Thus, unique hurdles exist for designing and deploying large display groupware applications (LDGAs) that are useful and adopted into actual work practice. We seek to understand and address these challenges through experimental design based on studies of workgroup practices, the formation of a set of heuristics for LDGA adoption, and validation of the heuristics through use in the design and analysis of LDGAs.

For the purposes of this research, we define LDGAs to be those technologies that make use of physically large display technologies such as projection, large plasma, LCD, or CRT screens to support workgroup practices including collaboration, information dissemination, and communication. In terms of the physical properties of the displays, we focus specifically on vertically-oriented “wall” displays as opposed to horizontal “tabletop” displays in this research. Additionally, we have limited the scope of this work to considering those applications designed explicitly to support workgroups, rather than those that are simply intended to support multiple users. In making this distinction we are excluding some presentation and classroom large display systems and purely public display systems such as airport information monitors that are not designed to support any explicit group practices, and for which the audience may be a collection of individuals that do not necessarily constitute a group. While some of these systems may be of value in supporting group practices and tasks, we focus this research specifically on those systems designed explicitly for workgroups and work environments. We believe that this subset of large display applications inhabits a unique and interesting area of the design space because the vertical displays, with their high degree of visibility, lend them to a combination of interactive and passive use and value, whereas tabletop displays are less visible from a distance and suited to discrete, interactive work sessions. Vertical displays seem to carry different potential for attracting passersby and being casually appropriated. Additionally, we believe that scoping our area of research to those displays designed specifically to support workgroups and workgroup tasks is of value because adoption of a technology by a workgroup seems qualitatively different from use of a public display application or a general purpose presentation tool. Adoption of an LDGA necessarily entails explicit or implicit acceptance of the technology by the group for the purpose of facilitating some sort of interaction among group members. Use of public displays or adoption of more general multi-user systems may be adopted simply because individuals decide to use them.

1.2 Challenges in Large Display Research

While large displays are becoming increasingly ubiquitous in work environments and other settings, groupware applications for large displays remain uncommon in everyday tasks and practices, despite the emphasis on such systems in research within the realms of HCI, Ubiquitous Computing, CSCW, and related fields. Few of the interactive groupware tools developed for large displays can be considered “killer applications” as few have been widely adopted and commonly used on large displays. Despite the prominence of research on large display applications that are dynamic or interactive, the most common uses for large displays for work tasks, such as use for presentations or to display artifacts or content, are passive and have not changed substantially in recent years. Workgroups that employ large displays for these tasks, generally do not interact directly with the display.

In general, groupware applications for large displays have not been widely adopted [Huang *et al.* 2006], and in this research, we seek to understand the challenges and barriers to adoption. Additionally, we seek to understand what makes some large display groupware applications successful, and leverage these findings to offer suggestions for design that help improve use and adoption of these applications.

The evaluation of large display groupware also poses interesting challenges for our research. Because of their public and shared nature, we expect that large displays are generally used less frequently than personal desktop machines. We would expect that a large shared display that was successfully adopted in the sense that it has been integrated into everyday work practices would still be used less than conventional machines in most circumstances. It is therefore important that we evaluate the success of these applications accordingly, looking specifically at how well they support and are used for the tasks for which they are designed, and how well they support workgroup needs when a large electronic display would be necessary or beneficial, rather than simply considering frequency of use. In this work, we conduct extensive evaluations of several individual LDGAs, including our own LDGA systems [Huang *et al*. 2002b, Huang & Mynatt 2003, Huang, Russell & Sue 2004]. Additionally, we recognize that shared technologies must be examined in context; as large shared displays are almost never a user's primary display surface, we evaluate the use of a particular LDGA, the NASA MERBoard [Trimble, Wales & Gossweiler 2003], within the greater "display ecology" formed by the many display technologies present in the work environment to better understand the role that this display plays in the workgroup.

1.3 Thesis Statement and Contributions

In this dissertation we seek to uncover and address some of the primary challenges of large display groupware applications though the design, development, deployment and evaluation of LDGA systems, as well as through the analysis of existing deployed LDGA systems. The thesis statement for this research is as follows:

> *By analyzing the common uses, adoption, and role of large display groupware deployed within work environments, we derive a set of principles that can guide the design of these technologies and can help to explain the adoption and use phenomena surrounding both standalone large display groupware systems as well as large displays within the context of a display ecology.*

We validate this thesis statement by undertaking research activities that address the challenges for large display groupware that we have presented. We develop an understanding of the common uses, adoption, and role of large displays by studying work group practices and designing, deploying, and evaluating LDGAs that support these practices, as well as by evaluating external LDGA systems. From these experiences, we derive the principles by analyzing the adoption phenomena across the many systems that we have studied. We demonstrate the value of the framework as a set of guidelines for design by applying them to the design of a novel LDGA and analyzing its subsequent adoption success through the lens of this framework. Finally, we assess the framework's explanatory power by using it as a tool for analysis in a long-term evaluation of a large display groupware system within a display ecology. More formally stated, the research contributions of this work to the HCI, CSCW, and Ubicomp communities are:

- *The design, deployment, and evaluation of LDGAs that foster awareness and communication, based on existing group practices* – By studying existing work environments and group practices, we identified communication, collaboration, and information awareness needs that had the potential to be supported and augmented with the use of large display groupware applications. These applications offer contribution by illustrating that large displays based on existing group practices can be beneficial to workgroups. Conducting these explorations into the design space of large display groupware also helped us to understand the difficulty of introducing and integrating these technologies into work environments, and helped us to identify some crucial inherent differences between large display groupware and conventional groupware that served as a basis for this work.
- *The development of a framework of LDGA adoption factors based on studies of LDGA adoption that can be applied to LDGA design and evaluation* – By studying the adoption and use of a broad set of LDGAs that had been deployed in workplaces, we identified several factors of design and deployment that related to adoption success. The resulting framework addresses the challenges for large display groupware by offering design and deployment guidelines based on real deployments to help promote successful adoption. The framework also can be used to help systematically analyze adoption success to ease the challenge of evaluating these systems.

- *Understanding of the role of large displays in complex work environments within the context of a display ecology* – Long-term deployments of large display groupware applications in very authentic work settings are rare; the majority of evaluations of large display groupware have been in the context of research deployments or laboratory studies; most of these systems have been studied in isolation, looking specifically at interactions with that particular system. This work contributes to the area by presenting an in-depth analysis of large displays within the context of a complex and authentic display ecology, with a user population unaffiliated with the designers and researchers of the system

1.4 Cross-Cutting Themes Explored in this Dissertation

In achieving the contributions described above, we also explore major themes that have cut across the various components of this research. In addition to the focus on the adoption of large display groupware, a key theme unifying the research in this dissertation is situatedness and its effect on use and acceptance. By situatedness, we are referring to the context in which the LDGA is deployed and used, including aspects of the physical location, audience, and characteristics of the environment. Some of the aspects of situatedness that we explore throughout this work include group size, the semantic meaning of the space, and the display ecology in which the LDGA exists.

Group size: In designing systems and analyzing other deployed LDGAs, we also explore the notion of group size, and how to tailor content to that size for interest and relevance. We explore this most explicitly in our designs for Semi-Public Displays [Huang & Mynatt 2003] and the Awareness Module [Huang *et al.* 2002b] in Chapter 3. Our design for the 20+ person audience for the Awareness Module reflects the desire for higher-level general-interest information, whereas the design for the 8-12 person audience for Semi-Public displays reflects the need for low-level, more personal content of a more day-to-day nature. The connection between content and group size also plays out in the use of the MERBoard (Chapter 6) for both small collaborations and passive display to the group of 40+ scientists; content displayed to the group as a whole tended to be high level, not explicitly tied to any individuals, and of general interest.

Semantic meaning of the space: The physical location of an LDGA, including the meaning and purpose of the environment, is an important component of its situatedness. This physical location is something that we have taken into account in all of our designs, in terms of what the LDGA is intended to support as well as what content is appropriate for it. The Semi-Public Display was located within a workgroup's personal workspace, not easily accessible by outsiders, thus lending itself to the sharing of personal and personally identifiable information. The Awareness Module and IM Here (Chapter 5) were located in shared group space, that was near but outside of personal workspace. This situation made them more appropriate for opportunistic viewing and interaction by passersby. In designing and evaluating IM Here, we were particularly interested in the impact of the space, selecting a location that was associated with a work hotspot, and generally well-trafficked [Huang, Russell & Sue 2004]. Additionally, the space was an information hotspot as well, containing information about a conference room schedule, printed posted notices, and event advertisements, all of which affected the use of the application.

Display ecology: A major theme of this work that emerged from our increasing understanding of the importance of situatedness on use and adoption is that of the "display ecology." In evaluating IM Here, we identified the influence of external objects and information in the environment on the system's use, particularly the proximity of another display that showed a conference room schedule. In studying the use of the NASA MERBoard (Chapter 6), we explored the notion of the display ecology in greater depth, noting the interdependencies and influences on MERBoard use imposed by the presence of the many other display technologies in the work environment. Both of these examples demonstrate how display ecologies can arise through the simple juxtaposition of different display technologies within an environment, shaped by the varied affordances, content, and purposes of the displays. Display technologies that were not designed to work as a together, do not form a unified system, and may not even be accessible from one another may still be used in conjunction with one another to form a support system of displays for users. Particularly in the case of the MERBoard display ecology, users made use of the MERBoard within the context of this organic set of displays by migrating tasks and content among them as it suited their dynamic needs to do so. Through this work, we come to understand not only the value of LDGAs as standalone tools, but how their role and value develops and is shaped by their situation within a display ecology.

1.5 Overview of Dissertation

In this chapter, we have introduced the class of large display groupware applications and motivated their study as a relevant and valuable subject of research. We have presented the thesis statement of this work, and discussed the contributions made by this research. In the remainder of this dissertation, we will present the contributions and research activities in detail.

In Chapter 2, we will present a summary of research related to the field of large display groupware. In this section, we will also present related projects within multiple formulations of the design space of awareness applications and large display systems.

In Chapter 3, we will describe our designs for two groupware applications, the Awareness Module [Huang *et al.* 2002b] and Semi-Public Displays [Huang & Mynatt 2003], that use large displays to foster awareness within workgroups. We will describe how the two applications addressed the same underlying goal, but varied in their design as a result of the differing needs, social norms, and physical space layouts of their target user populations.

In Chapter 4, we will present the Five Factors Framework [Huang, Sue & Russell 2003, Huang, Russell & Sue 2004, Huang *et al*. 2006] for the design and deployment of large display groupware, and discuss how we derived this framework by studying several large display groupware projects of varying adoption success.

In Chapter 5, we will discuss the application of the Five Factors Framework to the design of LDGAs, specifically to IM Here [Huang, Russell & Sue 2004], a system that we developed to make instant messaging (IM) available throughout the work environment on large displays.

In Chapter 6, we present the findings of a yearlong in-depth field study of the NASA MERBoard large interactive display [Huang, Mynatt & Trimble 2006] designed to support the scientists and engineers involved in the Mars Exploration Rover missions. We evaluate the success of this system in the context of the display ecology of the work environment. We uncover how use evolves over time in the context of a multi-display environment and make suggestions for how to evaluate large displays and multi-display environments based on our findings.

In Chapter 7, we revisit the Five Factors Framework in light of our findings from the NASA MERBoard field study. We use the findings from MERBoard to reflect on the explanatory power of the Framework, to understand the importance of the five factors in the MERBoard adoption case study, and to understand what aspects of use and adoption of the MERBoard cannot be traced to design and deployment.

In Chapter 8, we present some concluding remarks on the research presented in this dissertation, and discuss possible future directions for this research, including continued studies of multi-display environment use and identification of the unique factors affecting their success, and our continued work studying new deployments of NASA's interactive displays for workgroup activities.

The following table (Table 1-1) presents the research activities of this work in greater detail:

Table 1-1. Dissertation summary of research activities.

Activity	**Method**	**Research Products**	**Results**	**Chapter**
The design of LDGAs to improve workgroup information awareness among colleagues	Formative field studies, design, deployment, and evaluation	The Awareness Module, Semi-Public Displays	Systems designed to take advantage of the specific social norms and practices of workgroups will be most accepted and effective for fostering information awareness [Huang *et al*. 2002b, Huang & Mynatt 2003]	Chapt. 3
A framework of socio-technical factors affecting the adoption of LDGAs	Survey field study, in-depth field study, design, deployment and evaluation	Five Factors Framework for LDGA adoption	Through the study and evaluation of LDGAs, we can develop a framework for adoption that can serve as a set of general design guidelines and a lens for analysis of LDGA adoption [Huang, Sue & Russell 2003, Huang, Russell & Sue 2004, Huang *et al.* 2006]	Chapt. 4
The design of LDGAs intended to improve informal communication while users are mobile within the workplace; validation of the Five Factors Framework as LDGA design guidelines	Formative field studies, design, deployment, and evaluation	IM Here	The combination of large public displays and instant messaging facilitates important informal communication in workspaces outside of personal space; use of the Five Factors Framework as design guidelines influences successful adoption [Huang, Russell & Sue 2004]	Chapt. 5
In depth evaluation of an external LDGA system in a real-use setting within a greater ecology of display technologies	In depth post-hoc field study, data analysis using framework.	NASA MERBoard evaluation	The use and adoption of an LDGA evolves within an ecology of other display technologies that affect its emerging role and value [Huang, Mynatt & Trimble 2006]	Chapt. 6
Assessment of framework based on finding from in-depth display ecology	Data analysis including inductive analysis and open coding	Five Factors Framework assessment and refinements	The Five Factors Framework can account for many of the successes and challenges faced by the MERBoard, though some factors must be more broadly defined. Additional findings point to adoption issues that do not stem from design and deployment	Chapt. 7

CHAPTER 2

BACKGROUND AND RELATED RESEARCH

In this chapter, we present background information on large display groupware, and address what makes it a unique class of applications. We discuss the related research in the areas of large displays, large display groupware, awareness applications, and multi-display environments. We begin by discussing some of the theoretical works that have influenced and shaped our research and foci.

2.1 Theoretical Influences

One of the main theoretical influences on this work is Grudin's 1994 analysis of challenges for the design of groupware [Grudin 1994]. Grudin approaches groupware holistically, considering economic, technical, social, and organizational challenges that affect the uptake and value of groupware in workplace settings. The analysis is one of the first comprehensive examinations of CSCW technologies, and was conducted at a time when groupware existed primarily on single-user desktop machines in workplaces. While the lessons presented continue to be relevant for modern groupware, one of the aims of our work is to understand how the use of large displays affects groupware use. The fact that large displays are used differently from conventional desktop displays suggests that the challenges that Grudin exposes may affect large display groupware differently. Large displays may also face additional adoption and use challenges. Our work uses Grudin's analysis as an inspiration and loose model, aiming to answer similar questions specifically in the realm of large display groupware. His analysis addresses general, high-level patterns of design, deployment, and use, rather than the specifics of tasks, goals and functionality. Like Grudin's work, the theoretical analyses that we present here are not intended to account for the relative adoption success of all large display groupware applications, nor are the design and deployment guidelines that we propose intended to suggest that we can prescribe rules for large display groupware that will guarantee successful use and uptake.

Another theoretical influence of this work is Davis and Bagozzi's Technology Acceptance Model (TAM) from the field of Industrial and Systems Engineering [Davis 1989, Davis, Bagozzi & Warshaw 1989]. This model is intended to predict whether a technology will be accepted by users based on two factors: perceived usefulness and perceived ease of use. This model has been show to be consistently successful in predicting technology acceptance [Dillon 2001]. Because the technology must be fairly developed before users can form perceptions regarding usefulness and ease of use, TAM is typically used as a way of selecting a system from among competing technologies after they have already been designed or developed, as opposed to being employed in the design process. TAM has influenced our work because of its strong emphasis on the importance of user perception of the technology; in our work we have focused effort in creating design guidelines for large display groupware applications that attempt to create perceptions of value among potential users. In relation to TAM and Grudin's work, our factors for LDGAs especially emphasize design and deployment that will maximize users' perception of their colleagues' use of the system, as creating a perception critical mass is crucial for conveying the perception of usefulness.

2. 2 Physical Aspects of Large Displays

Large display applications have been developed and researched for a number of purposes, ranging from expansive single-user desktop workspace to output-only information displays in highly public locations such as airports to interactive whiteboards for group authoring of documents.

These technologies hold great potential for supporting workgroup interactions; their physical properties make them appealing technologies for supporting shared content for group viewing and collaboration on shared artifacts. The physical size of these displays makes them highly visible, thus offering potential for use as a shared visible workspace. This potential suggests that these technologies may be useful for co-located, synchronous multi-user interactions, displaying information for presentations to a group of users, or other uses in which it is valuable to be able to see others' interactions with information, documents, or digital artifacts. Physically large displays are also visible from greater distances than conventional desktop monitors, thus making them appealing surfaces for displaying ambient information, information relevant to a group, or of interest to passersby in shared space.

Large displays also seem to suggest interactions of a physical nature; the large work surface offered by interactive large displays lends itself to physical and tangible [Klemmer *et al*. 2001] interactions, such as gesture [Vogel & Balakrishnan 2004] or pen-based input [Mynatt *et al*. 1999]. Touchscreens and touch-sensitive systems [Ringel *et al.* 2004, Russell & Gossweiler 2001, Trimble, Wales & Gossweiler 2003] are also common in conjunction with physically large displays. Several large display applications also incorporate an understanding of physical presence by detecting people nearby and adjusting content or functionality based on presence [Everitt & Klemmer 2003, Streitz *et al.* 2003, Vogel & Balakrishnan 2004].

2. 3 Unique Properties of Electronic Large Displays

Large digital displays are unique technologies, in many ways different from both conventional desktop monitors, and non-digital shared work surfaces such as flipcharts or conventional (non-electronic) whiteboards.

While large electronic displays offer several of the advantages of conventional shared work surfaces, such as the ability for multiple people to work simultaneously on a single artifact and visibility from a distance, electronic displays have the potential to provide several enhancements. Digital displays allow users to save data or artifacts in electronic form, and the same work surface can therefore be reused. Digital storage also offers the potential for retrieval and editing or augmenting at a later time. Additionally, data from a large display can be stored losslessly and it can also be duplicated exactly. Because these displays can be networked, content can distributed to others, transferred onto other devices, or imported from external devices; these capabilities hold particular value for group uses of the display. Because networked electronic displays do not have the same constraints as conventional shared work surfaces, many interactions and tools are possible on such displays that would not be possible on conventional surfaces. For example, it is possible for users to interact with these displays remotely from other devices. In additional to novel interactions with large electronic displays and also in contrast to conventional shared work surfaces, users can often also apply conventional desktop machine tools or tools derived from conventional desktop tools, such as web browsers or word processing programs to the use of large digital displays.

2. 4 Unique Properties of Large Display Groupware

Large displays are an especially effective channel for group tasks and group viewing not only because of their physical size, but also because they are perceived as more public than conventional desktop displays. Work by Tan and Czerwinski has shown that people are more likely to view content on a large display than a conventional monitor, even when they are equally accessible and have a comparable size-to-distance ratio [Tan & Czerwinski 2003]. Their findings serve to further distinguish large display groupware research from related research on single display groupware [Bederson, Stewart & Druin 1999 Tse & Greenberg 2004].

The physical properties and electronic capabilities of large displays offer great potential for employing these technologies to support group practices and interactions. Despite the ubiquity and success of conventional desktop groupware in today's networked world, the creation of successful groupware for large displays is not simply a matter of translating conventional groupware tools to large display systems. As previous research has found, the interaction techniques that are appropriate for desktop applications are not necessarily appropriate for large displays, and people perceive large displays differently than conventional displays [Baudisch *et al.* 2003, Bezerianos & Balakrishnan 2005, Parker *et al.* 2005, Vogel & Balakrishnan 2005]. Applications successful on conventional desktop machines are not necessarily successful on large displays. Our research addresses the unique challenges for the design and adoption of large display groupware applications. Previous work by Grudin outlines the critical challenges for the creation and deployment of groupware applications for desktop systems [Grudin 1994, Grudin & Palen 1997], many of which also apply to the design of groupware for large displays. However, several unique features of large display systems that distinguish them from desktop applications heighten existing groupware challenges and present new ones. Some of the important inherent properties of large display groupware that make it experientially different from conventional groupware are:

Form factor – The physical size of large displays affords different types of interactions and visibility. Unlike desktop groupware, large display groupware is viewable from a greater distance and multiple users can view and interact with them simultaneously. As a result, their size and visual impact affects how users perceive and want to interact with them.

Public audience and location – Large display groupware is usually located in shared space; the fact that these displays are generally more public than desktop monitors affects the amount and type of attention that users direct toward them. Additionally, interactions with the large display are often more visible and less private than interactions with desktop groupware.

Not in personal workspace – Because large displays are usually located outside of an individual's immediate personal workspace, users interact differently with them than with groupware that resides on a desktop machine they use for several hours a day. Specifically, users may be less willing to spend time exploring and figuring out how to use large display groupware than groupware that exists in their personal workspace.

Not individually owned— Large display groupware applications are generally regarded and treated as a group resource; they carry less of a sense of personal ownership and responsibility for use and content than users feel for a personal desktop groupware client; this difference affects the extent to which people use the applications, and the ways in which they interact with the content.

These properties and the use and adoption of large displays that arise from them are discussed in greater depth in Chapter 4 of this dissertation, but are presented here as initial observations to help frame our discussions of large display groupware as a unique class of applications.

2. 5 Tabletop and Wall Displays as Groupware

In the realm of groupware, large displays have been used both in vertical (wall) and horizontal (tabletop) orientation [Rogers & Lindley 2004]. Of particular interest to us are those systems that take advantage of the physical properties of large displays such as size and visibility that make them appealing for multi-user interaction as well as passive or opportunistic information display. For this reason, we focus on the subset of large display applications that encompass groupware systems designed to support workgroup interactions through the use of upright, wall-type displays. Wall displays, including vertically-oriented free-standing displays, wall-mounted displays, and wall-projected displays, hold the greatest potential for fostering combining interactive use and passive value; unlike tabletop displays they offer visibility of content from a distance and therefore can be of benefit to users through ambient or opportunistic information even when users are not located directly in front of the display, or interacting with it actively.

There, is, however, currently an increasing amount of focus being devoted to the research area of tabletop displays because of their potential for co-located, synchronous collaboration and afford greater privacy because they are not easily visible to people not seated at the table. Recent work on tabletop displays for groupware focuses on document and artifact sharing and physical interaction with the display [Ringel *et al.* 2004, Kruger *et al*. 2005], the use of audio as an additional information channel for tightly coupled group tasks [Morris, Morris & Winograd 2004], disambiguating document and artifact orientation on horizontal displays [Matsushita *et al*. 2004], and space partitioning on shared tabletop displays [Scott, Carpendale & Inkpen 2004]. Additional work on tabletop displays has looked at toolkits for developing tabletop interactions [Shen *et al.* 2004].

2. 6 Large Display Groupware Projects

Several recent and current projects, including Dynamo [Izadi *et al*. 2003, Brignull *et al.* 2004], MessyBoard [Fass, Forlizzi & Pausch 2002], Plasma Poster [Churchill *et al*. 2003, Churchill *et al*. 2004], The Notification Collage [Greenberg & Rounding 2001], and GroupCast [McCarthy, Costa & Liongosari 2001] use large shared vertically-oriented displays as a means of promoting awareness and facilitating information exchange in different types of groups and spaces. Public displays have typically been utilized to promote awareness among larger groups, but the information they convey, such as live video and presence information, tends to trigger known problems of privacy, information relevance, audience targeting, and information scoping because of group size [Jancke *et al* 2001]. Additionally, previous work has shown that it is difficult to identify types of content for public display applications that are useful to general audiences. We have observed that small workgroups, however, are likely to have common interests, and therefore lend themselves better to peripheral group displays for awareness. Information that is of interest and relevance to many or all members of the group is more readily identifiable, and the individual members are more likely to seek information about others in the group.

Other work has explored the notion of awareness and public displays. The Notification Collage contains items posted by users within a workgroup, but rather than a single item at a time.. The What's Happening screen saver also addresses group awareness [Zhao & Stasko 2000], but does so through a window on the primary workstation, rather than a public display. BlueBoard provides information on a large, public display, but focuses more on explicit interactions for information management than peripheral awareness of group activities [Russell & Gossweiler 2001]. We will describe several of these projects in greater depth in Chapter 4 of this dissertation as background exploration for our Five Factors Framework.

In addition to group awareness and work task collaboration, several shared display applications have been developed for non groupware purposes. Projects by Streitz *et al*. such as hello.wall and Ambient Agoras [Streitz *et al*. 2003] use ambient displays to display personal information to users in public or shared locations, incorporating abstract visualizations to maintain privacy or create a certain aesthetic. These projects also incorporate the notion that information should be displayed and interacted with differently depending on the proximity of the users. Although these applications are shared in the sense that the displays are in shared space and are appropriated by different users over time, they are not strictly groupware in the sense that they are not intended to facilitate interaction among group members. Additional related projects make use of large shared displays for entertainment purposes, games, or conversation pieces in shared space. Some of these applications, such as Breakout for Two are highly synchronous and interactive [Agamanolis 2003], while others are passive displays that are intended primarily as artistic expressions.

While the related work that we have described above focuses primarily on groupware or multi-user applications for large displays, a considerable amount of work has also been dedicated to other aspects of large display research with potential value for groupware. These projects address issues such as low-level interactions [Baudisch *et al*. 2003], interacting with large displays using personal devices [Carter et al, 2003, Johanson *et al.* 2002, Johnanson *et al*. 2001], shadow elimination for front projected displays [Summet *et al.* 2003, Tan & Pausch 2002], large display hardware [Dietz & Leigh 2001, Matsushita *et al*. 2004 Winograd & Guimbretiere 1999] and infrastructure [Johanson, Fox & Winograd, 2002, Shen *et al*. 2004].

2.7 Situating our Research in the Design Space of Awareness Applications

Early in our research, we reflected upon our work in the context of other awareness applications work and large display groupware work, and in doing so have created multiple conceptualizations of the design space in which our designs reside. Our first attempt to map out the design space focused on the realm of awareness applications. By examining and categorizing several projects addressing the use of large and shared displays for the purpose of fostering workgroup awareness, we identified areas that were well-populated with projects, as well as areas that suggested further study. This first examination of the space and the identification of a potential "sweet spot" for design helped to motivate the research for the Semi-Public Displays project [Huang & Mynatt 2003] that we will discuss in chapter that follows.

We have analyzed many of the existing and past projects that address awareness between people and have found that they can be meaningfully subdivided along two dimensions (Fig. 2-1). First, awareness applications can be categorized by the type of

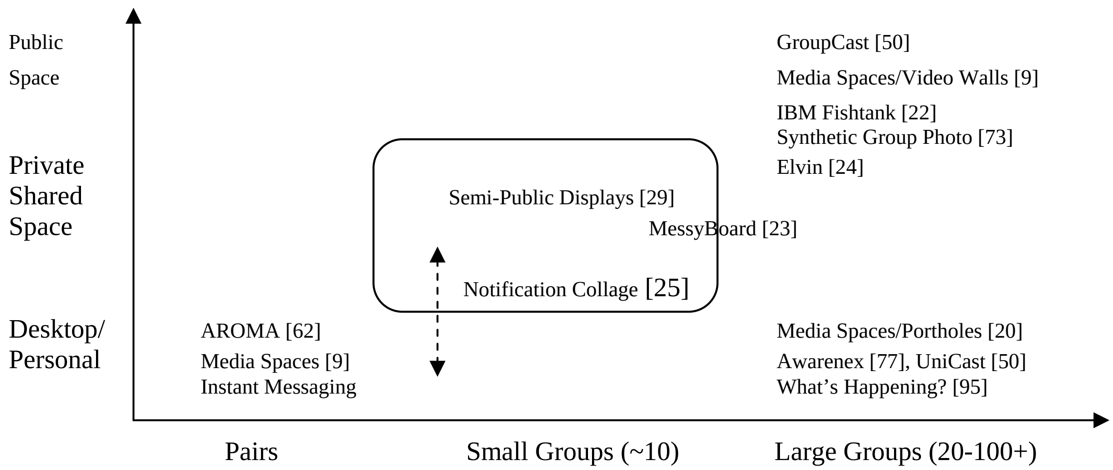

Fig. 2-1 An illustration of the design space of awareness applications categorized by the group size they are designed to support and the type of space in which they are meant to be viewed. Our design addresses the largely unexplored space of shared public displays to support small, co-located groups, delineated by the box in the central.

audience they are intended to support. Applications have been built to facilitate awareness between pairs of people, as well as among groups of people. Applications that support groups typically target different types of groups such as a workgroup of five people, or a company of a hundred. Applications typically are intended to support only one of these audiences—pairs, small groups, or large groups. Additionally, we have examined the environments in which the applications are intended to be viewed and used. Applications typically reside on the desktop or other individually viewed display such as a PDA, within a shared private space such as an office or lab, or within a public space, such as the kitchen or lounge area of a building.

Looking at the space, we can see that much of the work on awareness applications falls into three areas: applications for pairs on desktop or individual displays, applications for large groups on desktop or individual displays, and applications for large groups in public spaces. The success of these applications is primarily dependent on two issues:

the ability of the application to provide *relevant content*, and the extent to which the application addresses *privacy* concerns. Applications deployed in public spaces intended for supporting large groups that provide low levels of general awareness have been most effective. Displays that indicate the presence or absence of group members [Smith & Hudson 1996] or video walls that allow for opportunistic conversations [McCarthy, Costa & Liongosari 2001] have been fairly successful in facilitating low-level awareness.

Applications intended for large groups that attempt to provide higher levels of awareness by providing more detailed information about individuals often face difficulties because of privacy concerns. It is difficult to make personal details available to large groups without impinging upon individuals' privacy. Because of the tradeoff between privacy and depth of awareness, the applications that have been most successful and useful for large groups have been those that provide less information. Another challenge for presenting detailed awareness information to large groups lies in the relevance of the information to its audience. Because it is unlikely that detailed information will be of general interest and relevance to all members of a large group, rather than a subset of that group, it is difficult to provide appropriate content for these systems. A further challenge is presented when such systems rely on the users to supply content explicitly. Because the information an individual can provide about herself and her activities and interests is unlikely to be of interest to the large group in general, individuals tend not to be motivated to supply content, or else have difficulty identifying appropriate content. As a result, systems for promoting awareness among large groups that rely on user-submitted content tend to encounter the challenge of paucity of content, and because the content is not general interest to much of its audience [McCarthy, Costa & Liongosari 2001, Zhao & Stasko 2000].

Desktop displays of applications for large group awareness exacerbate privacy concerns because it is difficult to assess who is looking at what information and how often. In contrast, public displays that exist in a shared social space that bring with them shared social mores and mechanisms for preventing abuse. Moreover, desktop interfaces for pairwise connections have the opposite effect. The privacy garnered by the personal display supports the depth and details appropriate for disclosure by a pair of users.

Clearly, some unexplored areas of the space defined by these dimensions make less sense for design. For example, if the intention of a system is to increase pairwise awareness between people, using a display in a public space is unlikely to be a good choice to support that goal. However, not all areas with potential for design have been explored in depth. We posit that the space of applications for small groups supported by displays in shared group space has been largely unexplored. Designing applications for this space is an important area of research for several reasons. First, detailed information about individuals is more likely to be of relevance to the group as a whole. It is easier to identify and present content that is going to be both informative and appropriate to its audience. Additionally, whereas the presentation of personal information to a large group may intrude upon an individual's privacy, such information may be more appropriate among a group of co-located co-workers, who are likely to share context and have more personal knowledge of each other. Finally, because the need for communication and collaboration within small groups is often greater than that of large, distributed groups, it may be more important for individuals in a small group to have access to information about their co-workers. The small group audience may benefit more from having access to awareness applications and their content than the larger groups for which most applications have been designed.

2.8 Large Displays and Physical Situation

In addition to the above categorization of awareness applications, we also sought to situate our work within the larger context of related research from a different angle. In our second conceptualization of the design space, we undertook to understand the meaning of physical situatedness and its relationship to large display applications. In our initial studies of large display applications, we came to see the importance of the *meaning* of a space and that the physical location of a display has a greater impact beyond the sheer number of viewers that the application will receive. In addition to yielding different sizes and types of populations, physical location carries a range of other characteristics including the nature of interaction and communication that takes place in the space, the perception of ownership of the space and thus the perception of ownership of applications housed in the space, and the persistence of temporality of people within the space. In light of these distinctions, we again reviewed several related research projects considering the locations in which they were deployed. From this analysis, we identified several categories of physical location in which the applications resided and some of their key features that have potential effect on how the large display applications would be used or perceived. This categorization of the design space is illustrated in the chart (Table 2-1):

Table 2-1 A conceptualization of the design space of large display applications according to key characteristics of the physical location of the display

Type of Space	Example of Space	Key Space Characteristics	Example Applications
Personal Workspace	Private or small shared office	• Owned by individual person or persons • Generally used for individual work • Individuals are generally resident in space • Generally inaccessible to group or person without permission or invitation	Kimura [Voida *et a*l. 2002], Flatland [Mynatt, *et al*. 1999]
Dedicated Group Workspace	Shared laboratory or open office space	• Owned by group • Used for individual or group work • Group is resident in space • Generally inaccessible to public or individuals outside of group without permission or invitation	Notification Collage [Greenberg & Rounding 2000], MessyBoard [Fass, Forlizzi& Pausch 2002], Semi-Public Displays [Huang & Mynatt 2003], MERBoard [Trimble, Wales & Gossweiler, 2003]
Community Group Space	Office hallways, office lounges	• Owned by group • Generally not used for individual or group work • Group is not resident in space • Sometimes, but generally not accessible to public without permission or invitation	Plasma Poster [Churchill *et al*. 2003], Groupcast [McCarthy, Costa & Liongosari 2001], IM Here [Huang, Russell & Sue 2004], Dynamo [Izadi *et al*. 2003], hello.wall [Streitz *et al*. 2003]
Appropriable Group Workspace	Office conference rooms, meeting rooms	• Owned by group • Generally used for group work • Group is usually not resident in space • Generally inaccessible to public or individuals outside of group without permission or invitation	BlueBoard [Russell & Gossweiler 2001], Designer's Outpost [Klemmer *et al* 2001]
Dedicated Function Space	Classrooms, auditoriums	• Often owned by a larger community, little sense of ownership by groups or individuals • Groups often migratory • No residents in space • Generally not publicly accessible without permission or invitation	iRoom [Johanson, Fox & Winograd 2002], eClass [Abowd 2000]
Public Space	Outdoors, some building lobbies, airports, etc.	• Populaton is migratory, little sense of ownership • Generally accessible without permission or invitation	Plasma Poster [Churchill *et al*. 2004], Palimpsest [Carter *et al.* 2004]

2.9 Multi-Display Environments and Display Ecologies

As we have continued to explore the design space occupied by the applications that we have developed, it has become increasingly apparent to us that applications are in large part defined by their situation and context in addition to their functionality. In the more recent portions of this work, we have been addressing this notion more explicitly, examining how large display groupware applications are being used within the context of a display ecology. We look at how a work group uses multiple display technologies to support tasks, and how the technologies within multi-display environments form flexible system of support for work activities. Although many multi-display systems have been developed and evaluated in research, there has been considerably less research done on multi-display environments in which the displays were not explicitly designed to form a single, coherent system.

Tools such as MessyBoard [Fass, Forlizzi & Pausch 2002] and the Notification Collage [Greenberg & Rounding 2000] support synchronous and asynchronous communication for collaboration and include a large display component though interaction is generally conducted from desktop machines in the workspace. Projects like CoLab [Stefik *et al.* 1997], ARIS [Biehl & Bailey 2004], iLand [Streitz *et al.* 1999] and iRoom [Johanson, Fox & Winograd 2002] focus on the architecture, system design, and interaction techniques of multi-display environments with a focus on how users can interact across the displays. These systems and environments have been evaluated primarily in laboratory studies, used only in research settings (often the home laboratories of the researchers), or in limited-term experimental trials. While the evaluations of these systems have yielded valuable findings regarding the value and use of large interactive displays for supporting group work, we still lack a deep understanding of what role these systems play in natural work environments over time.

A recent workshop on multi-display environments (both single-user and collaborative) [Hutchings, Stasko & Czerwinski 2005] included position papers that identified common types of multi-display environments [Shen, Ryall & Everitt 2005], as well as technical design considerations for such environments [Inkpen & Mandryk 2005]. Recent work by Wigdor *et al* has considered the positioning of displays within a workspace, particularly with respect to the location of vertical displays around a table or tabletop display surface [Wigdor *et al*. 2006a, Wigdor *et al*. 2006b]. This work also considers the roles of individual displays within such environments; specifically, the tabletop is generally conceived of as an interaction space, while the vertical displays are generally output-only surfaces.

In addition to our work on display ecologies, there exists a considerable body of research on designing and environments and interfaces for complex work situations. A framework for ecological interface design (EID), stemming from the field of ecological psychology has been proposed and extensively applied in designing complex systems such as those used in aircraft, and military control from a distributed cognition perspective [Hutchins 1995]. The EID framework emphasizes the importance of making the state of the system perceptible to the users to lessen the cognitive load of user tasks and help prevent unanticipated task difficulties [Vicente 2002, Vicente & Rasmussen 1992]. Rouncefield *et al.* apply an ecological lens to their ethnographic studies of office work environments as well, finding that the arrangement of physical objects within the workspace carries local meaning to its inhabitants that creates a shared awareness of the state of the work and offers cues about the responsibilities of the workgroup members [Rouncefield *et al.* 1994]. In this case,the ecology is defined by the presence and arrangement physical objects within the environment, but also includes the shared understanding of work and responsibility that is facilitated by this arrangement and the “local knowledge” possessed by the individuals that allows them to interpret the physical environment.

CHAPTER 3

DESIGNING LARGE DISPLAY GROUPWARE APPLICATIONS TO SUPPORT INFORMATION AWARENESS

In this chapter, we begin to explore the design dimensions of LDGAs through the design and deployment of two large display applications that address a similar goal but target different audiences in different environments. We conducted a pair of design projects to address the use of large displays for the purposes of increasing workgroup awareness at multiple granularities. The purpose of designing these systems was manifold; by designing, building and deploying these systems, we sought to:

- understand some of the information sharing needs of different types of workgroups;
- leverage groups' existing collaboration and information sharing practices in awareness systems that employ large displays;
- witness how groups and users perceive and adopt novel large display technologies in their environments; and
- understand and experience the differences between designing for interaction on large displays and desktop systems

To this extent, we designed two LDGAs, each with the purpose of fostering awareness within two different types of workgroup. The Semi-Public Displays project aimed to promote information awareness and informal collaboration between co-located members of a small, tightly-knit workgroup in an academic environment [Huang & Mynatt 2003], whereas the Awareness Module sought to provide high-level information sharing among members of a larger corporate research group whose members were distributed across a contiguous space and had varying levels of interaction with each other [Huang *et al*, 2002b]. In each of these instances, the objective of the application, types of content and information displayed, and input and interaction methods were based on formative studies of the specific workgroup's needs and existing practices. These experimental designs provided the groundwork for our initial understanding of the design space of large display groupware applications; they provided many valuable lessons about the value and impact of large displays for information awareness as well as the potential challenges for the acceptance and adoption of such systems. Although we began these projects with the same initial goal – to understand and design for the information awareness needs of each workgroup using large interactive displays, the variations in the workgroups' sizes, environments, social norms, and information needs pointed to two important differences between the groups: 1) the types of content workgroup members desired, and 2) the ways in which workgroup members wanted to view and interact with the content. These variations stemming from differences in the design dimensions led us to design very different systems for the two workgroups.

3.1 An Exploratory Design: Semi-Public Displays

The members of a co-located lab are likely to be highly aware of each other's activities; even so, we have identified several benefits that public interactive displays can offer in a small group setting. By making certain types of relevant information persistent in the environment, these displays can provide information about group members, and foster coordination and collaboration. We have found them to be a potentially effective medium for making information from other channels persistent in the environment, thus making information easily available and reducing the need for group members to remember or retrieve it from overloaded channels, such as email.

3.1.1 Design Motivations and Challenges

To explore the design of Semi-Public Displays, we designed a set of interactive applications for the Everyday Computing Lab of the College of Computing at the Georgia Institute of Technology. We use public peripheral displays in our academic lab environment because we believed they could provide many benefits to our group by supporting asynchronous collaboration, opportunities for sharing targeted information, and visual representations of lab activity. Because the information in these displays is intended to support members of a small, co-located group within a confined physical space, and not general passersby, we call our system a "Semi-Public Display."

Based on observations of practices for maintaining awareness and collaborating, we identified potential content for the system, limitations of current methods for sharing this information, and then sought to adapt this content to be effective and appropriate on a large shared display. In general, the types of information sharing in which the lab engaged entailed low-level, non-urgent informal information, often at a fairly high granularity, such as current and daily activities. In exploring the current methods the lab members used to maintain awareness of each other, we found they used information distributed across several methods and tools. In designing the system, we also aimed to provide users with a display on which they could have easy access to this type of information all at once.

One tool we examined was emailed status reports, which lab members compose and send to the members of the group on a weekly basis. These reports contain information about people's current work status, their work plans for the coming week, and requests for assistance with specific tasks. We found this information to be useful and effective in helping members maintain awareness of each others' work, but also found that the group members would forget about the help requests after reading the emails. We therefore believed that this content would be made more useful if it were more easily accessible and visually persistent.

Additionally we found that people made use of information such as instant messenger status cues, and colleagues shared calendars to maintain awareness of each other's schedules and presence in the space. While the calendars are useful sources of high-fidelity information, they require effort on the part of others to check them, and many of the group members do not maintain a shared calendar. We also found that one of the major reasons group members were interested in their colleagues' schedules was because they used that information as a way of helping them determine what upcoming events might be of interest to them. While using an individual's calendar may be an effective way of assessing which events are of interest to that individual, gauging which events are of interest *to the group* using individual calendars is time-consuming and less effective. Similarly, instant messenger status information provides users with a way of gauging whether group members have recently been active at their machines, but again is not as effective for reflecting *group* activity, or group presence over time.

After we identified the benefits and limitations of the various tools and methods used by group members, we designed applications to provide needed information, adapted for a shared group display.

We use a touch-enabled SMARTBoard™ to display the applications. Each application occupies roughly a quadrant of the space, forming a montage of persistently visible information (Fig. 3-1). In the following sections, we describe the information and interactions that we have found to be of importance to group awareness as the motivations for our system components, and the following four applications that we built to support the display and access of this information:

- *Reminders* – brief requests or facts displayed to foster discussion and enhance awareness of group members;
- *Collaboration Space* – designated shared interactive spaces for asynchronous group work;
- *Active Portrait* – a graphical representation of the group that provides an high level overview of group activity and presence over time; and
- *Attendance Panel* – an abstract visualization of planned attendance at upcoming events to reflect group interests.

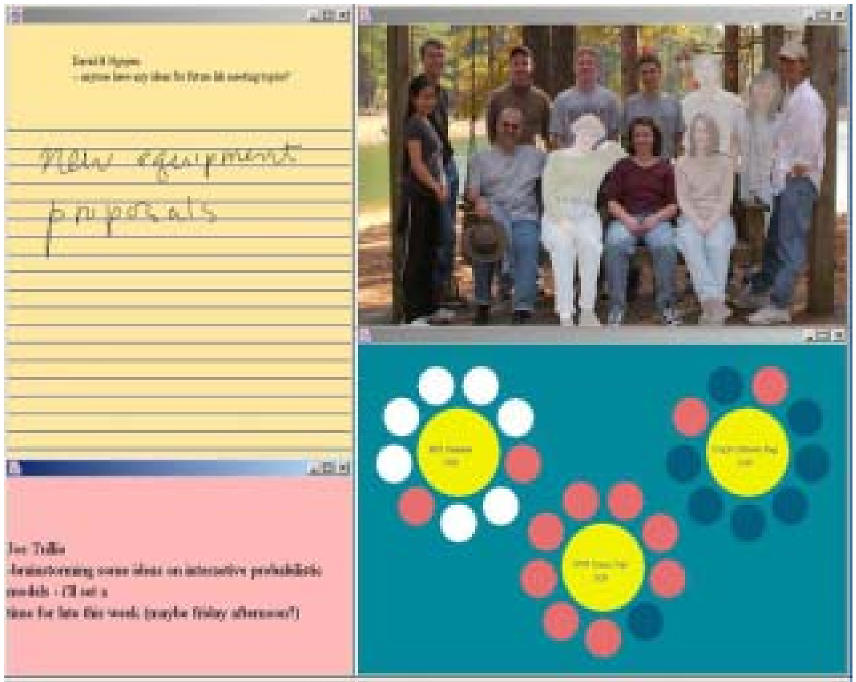

Figure 3-1. Semi-Public Display prototype. Clockwise from top left: a) Collaboration Space; b) Active Portrait; c) Attendance Panel; d) Reminders

3.1.2 Reminders and Collaboration Space

The Everyday Computing Lab currently makes use of weekly status reports that are sent via email to all of the group members. While these reports are a rich source of information and valuable for promoting awareness of group members' activities, the email medium does not maximize their utility. We have identified information contained in these reports that would be most useful if they were kept persistently visible in the environment. For example, when one member of the lab sends out a report to her labmates containing the request, "If anyone has some time, I'd like some help revising my CHI submission," lab members may be willing to help, but without regular email reminders, they may forget, necessitating another mass email. Lab members often write these sorts of help requests once in the weekly report, but find that they need to repeat themselves to get the help they need. Because the information already exists, we sought to find a way to obviate repeated requests.

Our system uses a slideshow-style application to display these help requests and reminders on the Semi-Public Display (Fig. 3-1d). The text of these requests then becomes part of the environment and serves as reminders to colleagues. We use a simple Perl parser on the text of the status reports to extract help requests; we then cycle through the requests, displaying each one for a few minutes at a time for the duration of the week. Though simple, it provides persistent access to this information in the environment, and, unlike repeated emails, is non-intrusive in people's personal workspaces. Because the volume of help requests is generally low (fewer than a dozen per week), each request is displayed frequently enough that it is unlikely to be missed by people working in the space.

In addition to reminders, we found that the status reports also contained requests for more immediate feedback and collaboration. We wished to support this by facilitating asynchronous brainstorming, creating a forum in which collaboration could occur outside of discrete meetings and sessions. Although group spaces are often equipped with whiteboards for collaboration, an examination of our group's usage of whiteboards showed that they were best suited for synchronous collaboration because of the static nature of their content. After a group work session, the content of the whiteboard was not later edited or worked on by group members. The content ceased to be dynamic afterwards because it was unclear if group members would notice new changes, and content ownership was ambiguous.

By creating a space for collaboration for the Semi-Public Displays, our aim was to provide a dynamic, captured space that was clearly designated as editable and viewable by anyone at anytime. Again, using help requests extracted from the weekly status reports, we cycle through the items, displaying each one for several minutes at a time, and provide a space in which users can create and edit ideas. People interacting with the display can add content using freeform ink and gestures provided by the SATIN toolkit [Hong & Landay 2002], and the content affiliated with each item is captured and redisplayed every time the item is shown (Fig. 3-1a). Unlike conventional whiteboards, whose content group members are often wary of erasing, editing, or adding to outside of brainstorming sessions, our design keeps the request visible and provides an explicit space for brainstorming and scribbling at all times. The inked content is attached to the help requests and is displayed and editable every time the request is shown.

A number of other applications address offloading knowledge and retrieval by putting awareness information in the environment. Related work includes the Notification Collage, upon which users can post items of potential interest to the group [Greenberg & Rounding 2001]. The What's Happening screen saver also displays information about individuals for group awareness, but targets a much larger audience for the purposes of making large, loosely connected groups of individuals aware of each other's activities [Zhao & Stasko 2000]. Our application differs from these in that it is intended as a reminder system and collaboration space to support and enhance existing channels of information exchange and collaboration. Additionally, it is designed specifically for the interaction dynamics of a co-located group.

3.1.3 Active Portrait

We observed that lab members also make use of instant messenger status cues to obtain context about the other members of the lab. These cues provide information about whether someone has been recently active at his computer. Understanding the context of the physical lab space, including who has been present recently, is important for fostering collaboration and group work. We aim to provide easy access to information about presence and recent activity in the lab space. While instant messenger status cues are a good way of providing specific information about individuals, we wanted to provide a broader picture of recent activity in the space, not specific whereabouts or accurate counts of idle time. We sought to provide an at-a-glance visualization to provide context about group presence in the space, but abstracted to maintain individual privacy.

The application that we use to display an abstract representation of group activity consists of a group photograph of the lab members (Fig. 3-1b). In this "active portrait," each person's image is displayed in full color if he or she is present in the lab. A person's image fades slowly over time when he or she leaves the lab. If a group member has not been in the space for several days or more, his image fades nearly to white by increasing lightness and decreasing color saturation, but retains some color value for recognizability. The resulting composite image provides viewers with a quick, at-a-glance picture of colleagues' recent presence in the lab. It allows the viewer to have some context about lab activity, especially when she has just entered the space. Unlike tools such as shared calendars or in-out boards, however, the image does not provide specific information about the exact times when a person left or entered the space, or a person's current whereabouts.

Our design provides low-fidelity presence information to give an overall picture of group presence, unlike instant messenger status, which gives high-fidelity information about presence, usually accurate to within minutes. Like instant messenger status cues, our design also monitors keyboard activity on desktop machines to measure idle time.

The design does not, however, provide near-immediate information about whether a user is idle. Instead, individuals in the photograph fade slowly over a period of days to provide broader context about activity. Therefore, rather than conveying information such as "Beth has been away from her computer for 7 minutes," the Active Portrait allows users to make inferences such as "The lab has been mostly empty for the weekend" or "Most people seem to be around this morning."

Several other projects have addressed the question of how to visualize presence. IMVis uses a three-dimensional layout of an instant messenger contact list with graphical or photo representations of contacts with space as a metaphor for availability [Neustaedter & Greenberg 2002]. The Synthetic Group Photo allows users to create a custom layout of colleagues' images to track presence, like a graphical in-out board [Smith & Hudson 1996]. Piazza uses a similar graphical representation of users to display information about who is working on related tasks, though not necessarily in close physical proximity [Isaacs, Tang & Morris 1996]. Unlike these projects, our application is viewed collectively in a shared space, rather than on an individual's desktop. Farrell describes a system that uses a fishtank visualization on a large display to indicate presence and activity within a large group [Farrell 2001]. Our work differs from all of these projects in that it is intended to display an overview of group activity *over time*, and is designed for group display and access.

3.1.4 Attendance Panel

We have also found that group context is valuable in planning attendance at upcoming events; group members are likely to take an interest in an event if they know that their colleagues are planning on attending it [Grudin & Palen 1997]. Group calendars provide an individual with an overall picture of who is planning on attending an event, provided that other group members expend the effort to browse their colleagues' calendars. This interface, while useful, requires effort to use and check, and may disclose detailed information about people's personal calendars and schedules. We wanted instead to offer more abstract representations of planned activities, thus allowing group members to see a general picture of the popularity of upcoming events to infer group interest. Additionally, we wanted to adapt the information to make it appropriate for a persistently visible public display application, eliminating personal details to provide an easily understandable overview.

The application that we use to provide lightweight group awareness is the "attendance flowers" panel (Fig. 3-1c) on the Semi-Public Display. The panel displays several "flowers," which consist of a large circle with an event title as a label, surrounded by a ring of smaller circles. Each flower is a representation of an upcoming event, such as a seminar or a talk. When a user interacting with the Semi-Public Display touches the center circle of a flower, the event description appears. The smaller circles, or "petals," represent users. Each petal has three states: blue for "not planning on attending," bright pink for "planning on attending," and white for "haven't decided yet." When a new event is added to the panel, it creates a flower whose petals are all white on a blue background, signifying that no one has yet updated his or her status. If a user elects not to attend the event, he toggles one of the petals to the "not attending" state, which is a slightly darker blue than the background, therefore blending with it. If a user chooses to attend the event, she toggles a petal to the "attending" state, which is a bright pink, contrasting significantly with the background. Users are free to select any petal that has not already been taken; they are not bound to any particular position on the flower. Their identities, therefore, cannot be discerned by the position of the petal on the flower, thus protecting their privacy.

The colors of the states create a visual image that brings the petals in the attending state to the foreground, while camouflaging the petals in the not attending state. A viewer can easily discern what events are of importance or interest to the group, or of potential relevance to her, by noticing how "complete" the flowers are. This simple interaction and visualization allows users to view planned attendance at near future activities, without compromising group members' privacy.

The practice of using information about colleagues' schedule to inform one's own event attendance has been observed in labs outside of our own [Grudin & Palen 1997]. Related work includes the AWE system which investigated the effectiveness of providing information about colleagues' planned attendance as metrics to help users determine the potential relevance of upcoming events to their own interests [Huang *et al.* 2002a].

3.1.5 Pre-Deployment Study

We designed a series of questionnaires to evaluate the effects of and response to the Semi-Public Display over time. We have administered a pre-deployment questionnaire to our user population as well a post-deployment questionnaire.

We administered the pre-deployment questionnaire one day before the initial deployment of the Semi-Public Display to eight members of the group. The questionnaire consisted of open-ended questions intended to help us understand the methods people use for the following six procedures:

- maintaining awareness of group members’ day-to-day work status;
- maintaining awareness of group members’ ‘milestone’ work status such as publications, design phase, evaluation, paper writing, etc.;
- maintain social awareness of group members’ non-work activities;
- maintaining awareness of group members’ attendance plans for upcoming events;
- obtaining assistance with short-term tasks or immediate tasks; and
- initiating collaboration or obtaining help with longer-term tasks.

In addition, the questionnaire included 5-point Likert scale questions to help assess the extent to which users found these procedures important and how well they believed their methods worked.

Our pre-deployment study served to provide us with an assessment of the methods people were currently using to maintain the type of awareness that we hoped to foster using Semi-Public Displays. We found that people utilized a wide range of methods for accomplishing the six tasks and met with varying degrees of success in doing so.

One of the areas in which we found people’s awareness was most impoverished was in their knowledge of colleagues’ attendance at future events. Nearly all group members had a hard time keeping track of what events others are attending but felt that it was important information, influential to their own plans. Most users found their own methods to be insufficient for obtaining this information.

Lab members also expressed difficulty getting help with tasks, both short- and long-term. Obtaining assistance with projects, papers and technical questions was something that most people deemed very important, but many find that their methods were not effective, especially for longer-term tasks. For short-term tasks or quick help, most people relied on immediate information channels such as face-to-face conversation or instant messaging. These methods were largely successful when people could be reached. Solicitation for longer-term help, usually requested via email or face-to-face conversation often yielded less response. Group members felt that this failure was largely because people tended to forget the requests when not reminded of them.

We found that most group members felt fairly comfortable about knowing colleagues' work status at a large granularity, such as whether people were in the process of designing a system, doing studies, or writing papers. They felt that lab meetings and opportunistic conversation was mostly sufficient for maintaining this awareness. They felt less aware of group members' day-to-day project status, which they deemed to be somewhat important. Most felt that they were up-to-date on the project status of a few other lab members, but not on the group as a whole.

Finally we found that most group members relied primarily on opportunistic conversation to maintain social awareness of group members. Again, group members felt that they were highly aware of a few of their colleagues' activities. Maintaining social awareness however was not a task that many lab members felt to be important.

3.1.6 Post-Deployment Study

After the group had been using the Semi-Public Display for two weeks, we administered the first in a series of post-deployment questionnaires, that again consisted of both open-ended questions and 5-point Likert scales to help assess the extent to which the Semi-Public Display applications supported the six procedures.

As our pre-deployment study implied, people were highly responsive to the Attendance Panel. The application was viewed very positively, and users found the visualizations useful for maintaining awareness of others' plans as well as determining whether events were of interest to them. While users stated that the visualization itself was not a major determining factor for their attendance plans, some stated that they referred to it when an event seemed like it might be "marginally interesting." Although the application was often not a deciding factor for users' plans, most users said they found it "interesting" to have easy access to the information and thought that "the wall is a great place to display this kind of attendance information." The anonymity of the application proved to be unnecessary as well as undesirable; several users said they would find the application more useful because they could then use it to understand the attendance plans of specific people. This result leads us to believe that maintaining privacy for this application in this type of group may be unnecessary; people seem to be willing to share this type of info within this group.

The Reminder Panel also received good usage and was well received by users. They responded positively to the fact that the information was persistently viewable and afforded opportunistic glancing that assisted their memory. The application provided benefit both to the requester of the help and the viewer of the request, with users stating that the panel helped "remind me of ... outstanding issues that others have mentioned in their emails." Users found this application most useful in helping them maintain awareness of group members' day-to-day work status as well as for getting help with both short-term and long-term tasks because the requests were constantly viewable in the environment.

The Collaboration Panel proved to be somewhat more problematic. Users deemed it to be “more fun than extremely useful” and that the things people wrote on it were “interesting but not useful.” The application seems to provide a different kind of awareness than we intended in that users are looking at what others are writing, but it does not seem to provide as valuable a forum for collaboration in its current state as does face-to-face collaboration. In addition, many people complained of the fact that they found it difficult to use the inking on the display; they found it difficult to write and draw and were therefore not eager to contribute to it. This result leads us to believe that we will need to provide alternative methods of input to encourage further collaboration.

The Active Portrait also suffered as a result of technical problems. People found it difficult to distinguish and interpret levels of fading on the image, that it was “difficult to tell if someone is faded or just in shadow”; this problem was exacerbated by the fact that the projector washed the image out, making it considerably less bright than a traditional display. Users also found that it did not live up to its potential because of the inaccuracies yielded by keyboard monitoring data. Because group members often worked in the space but not at their machines, the presence information often did not reflect the recent group presence accurately. Some members, however, expressed the belief that the application had potential utility if it could be made more accurate. One user mentioned that he would like to use it as the equivalent of “checking if [someone’s] seat is still warm.” Despite the difficulties that users had interpreting the data, it seems that greater accuracy, perhaps through the use of RFID tracking rather than keyboard monitoring, and better image contrast may make the application useful for some of the lab members.

In addition to gathering data via questionnaires, we also evaluated the effects of the display through observations of its use as well as informal conversations with our users and have found it to be quite successful in generating interaction and disseminating awareness information among group members. Since the deployment of the display, we have observed a significant increase in the average number of help requests in the weekly status reports. Additionally, we have noted much conversation generated within the lab regarding the information items in the Reminder Panel as well as the user contributions on the Collaboration Panel. Finally, several users have mentioned the benefits of having the reminders persistent in the environment; opportunistic glancing has prompted them to offer assistance and information to group members who posted the information.

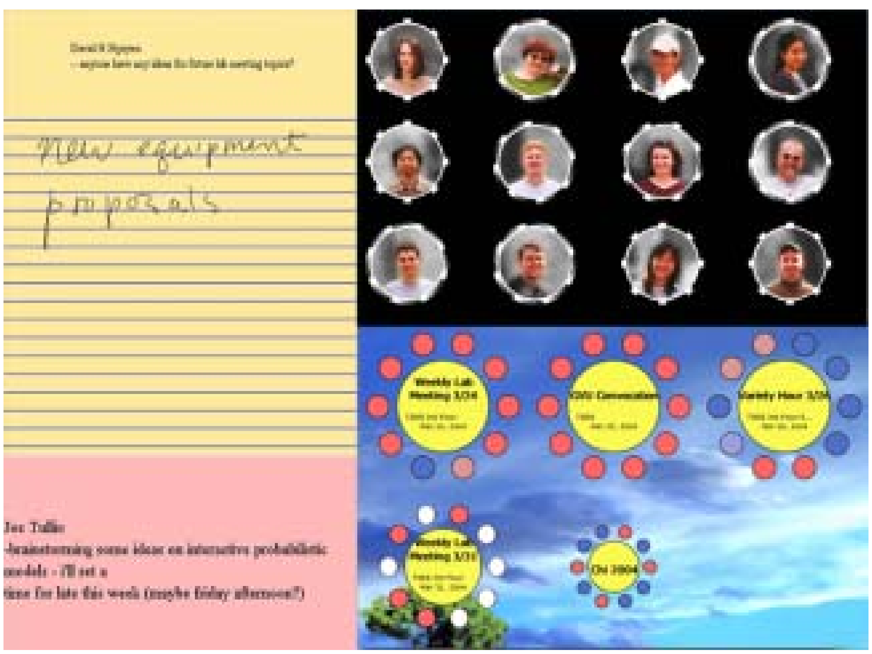

Figure 3-2. Design iteration on the original Semi-Public Displays prototype based on user feedback and a study of visualization alternatives

Since the time of this study, the design of Semi-Public Displays has undergone a iteration based on the feedback of this study (Figure 3-2), and, most notably, an additional study of alternative visualizations for group member presence. This redesign and study were led primarily by a researcher who was not involved in the original design and evaluation of Semi-Public Displays [Tyman & Huang 2003].

3.2 An Exploratory Design: The Awareness Module

The Semi-Public Displays project gave us particular insight into the use and adoption of a large display groupware system developed to support the specific needs of a small, co-located workgroup. To investigate a different area of the problem space, we also designed and developed the Awareness module for a larger corporate workgroup. As with Semi-Public Displays, we designed this system from the ground up, basing the interaction design and content choice on the existing needs and social practices of the specific workgroup.

Awareness gaps are an increasing problem in many organizations, including the research group at Accenture Technology Labs, which, at the time of this work, was composed of 50 people in three locations who were engaged in approximately 20 projects at any given time. Lab members were involved in conducting research, publicizing the research, commercializing the results of research and sharing expertise with others. As demands grew for the latter two tasks, with no corresponding reduction in the demand for the first two, members had less time for maintaining awareness of what others are doing. Thus they were in an impoverished position with respect to identifying opportunities for collaboration, routing information requests to appropriate individuals, and taking advantage of the latest skills and experiences of others.

In contrast to the workgroup for which we designed Semi-Public displays, the members of the Accenture Technologies Labs group had a greater sense of personal space ownership, with most of them working in cubicles and private offices. These isolated workspaces led to a much clearer distinction between private and public space; desk areas were owned by specific individuals and lounge and hall space was clearly owned by the group. In contrast to the more tightly co-located group, individuals had much greater control over what information and communication came into their personal workspace.

In informal conversations with the researchers, we found that most members of the group were familiar only with their own work and that of people who were doing work closely related to their own. Many expressed dissatisfaction with their knowledge of their colleagues' work. This observation led us to conduct a study to find the causes of the communication breakdown, and discover what types of information they desire.

3.2.1 User Study and Motivation

We conducted eight semi-structured interviews in which we asked participants for their thoughts on information dissemination in the lab, what types of information were of interest about their coworkers' activities, and what they wanted others to know about their own work. Nearly all participants expressed dissatisfaction with the channels through which they received information. The content of mass emails or electronic newsletters was often irrelevant or not of interest to them, and many objected to receiving email that they felt was unsolicited and distracting. All but one thought that the group's web page provided a good summary of mature or completed research, but not coworkers' *current* activities. They were also unwilling to check the pages regularly for updates.

Despite the complaints, all but one of the participants expressed a need to stay updated on others' work, and were enthusiastic about a tool that would provide information easily and on their own terms. One participant responded that he felt that everyone ought to be able to make an “elevator pitch”, a short summary, about the current work of every other person in the office to clients or others outside of the firm, but most people could not.

Most of the researchers were willing to input information about their own work into a system and already had ways of doing so, such as posting articles about their work on their cubicles, seeking out the people whom they thought might be interested and talking to them in person, or sending targeted emails. Each method had flaws: cubicle postings can only be seen by physically co-located people; informal discussions and targeted emails will likely miss others who would be interested. They did, however, demonstrate to us that the researchers already put some degree of effort into disseminating this information voluntarily.

We limited our user population to people who are interested in having access to information about coworkers’ status and in disseminating information about their own work.

Respondents typically desired information pertaining to milestone events, such as ventures, market offerings or other commercialization, opportunities for research, new projects, conferences, publications, and major meetings with people outside of the firm. In general, they were not interested in receiving information about people’s ordinary day-to-day activities or personal interests.

3.2.2 Design Goals and System Design

In designing a system to satisfy our users’ needs while avoiding the pitfalls of the current methods, we aimed to meet the following requirements:

- provide simple input interaction, requiring minimal effort on the users' part, comparable to the amount of effort they were already exerting to share information;
- minimize the amount of distracting or obtrusive information sent to users' personal workspaces;
- give users some control over what information they receive, and the depth of the information; and
- make information visible in the work environment, thus increasing general awareness, and making information available to everyone.

The Awareness Module is built on top of the Ubiquitous Peripheral Displays framework [McCarthy, Costa & Liongosari 2001] that supports multiple channels of information shown on displays other than primary workstations. The Awareness Module utilizes a large display located in a public area or the office, and an attached passive badge reader (Figure 3-3).

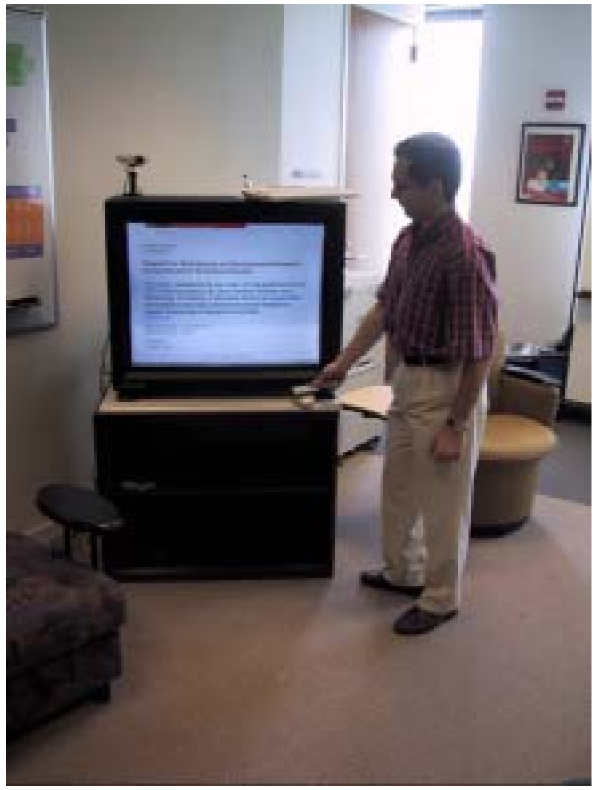

Figure 3-3. . The Awareness Module prototype deployed in an office common space. A user touches his ID badge to the RFID reader to have the current post sent to him.

Users input “awareness items” to the system at their desktop machines using a web-based form accessible from any browser. The form provides fields for a short blurb about an item of interest, an optional longer description and optional uploaded files. A user might go so far as to write up a comprehensive project description, or simply write a sentence or two about it, and attach an existing document, such as a conference paper or newspaper article.

The short blurbs are displayed randomly on the large public display for 15 seconds at a time, providing an experience similar to that of seeing headlines while walking past a newspaper dispenser. An example is shown below in Figure 3-4:

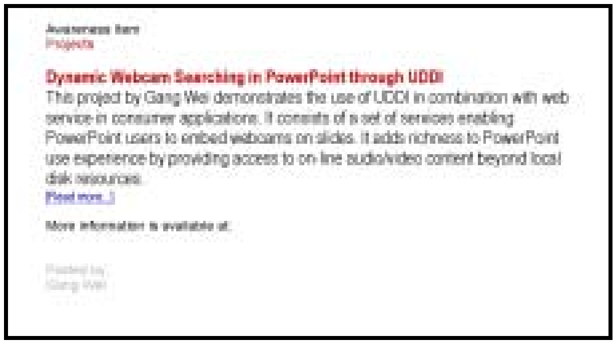

Figure 3-4. A sample screen from the Awareness Module showing a high level blurb about a project.

By selecting the "read more" option, the user sees the long description and documents associated with the awareness item. If the user wants to read it at another time, she can swipe her ID badge at the reader, and receive full text and documents via email. Using this interaction, users receive only the detailed information in which they are interested.

3.2.3 Prototype Feedback

As this work was done on internship with Accenture Technology Labs, time constraints prevented an extended deployment. The system was deployed for approximately three weeks, during which we collected qualitative feedback from group members. We deployed the Awareness Module prototype in the office in a well-trafficked hallway near several cubicles, and early feedback was very positive. In the first three days of deployment, about a dozen items were displayed, on topics ranging from new projects to conference participation. People were initially willing to compose descriptions and upload documents for their items. While users expressed concern that enthusiasm to create items might diminish over time, they also suggested that interest might increase if the system gave an indication if – or, even better, which or how many – people were viewing their items. This feedback might also encourage people to read an item, if they see that it is popular or new. We considered the addition of a visible "hit counter" or other feedback mechanism to encourage further posting, but time constraints prevented another design iteration.

We had several interesting instances of use of the new tool during the deployment. Several people noted that they became aware of a new project in the Palo Alto lab through an awareness item; people typically do not learn of projects in other labs until project leads present them in weekly videoconferences, which often does not occur until well into a project. Another item concerned a person who had changed jobs within the firm, which had not been known to most of the other members of the lab prior to its display on the public monitor. Another unexpected use was to post messages such as "I need to leave early today. If you need me, find me by 3:00" posted by a support person. All of these items might have been circulated via email, but people reported that the delivery via public display was preferable.

3.3 Design Lessons

Our examinations of the different practices, social norms, and work environment of these two groups led us to understand the importance of these concepts as dimensions in the design space of large display groupware. Specifically, the two groups varied along the following dimensions, thus affecting the type of desired content and the desired method of interaction:

- Degree of Co-Location – The extent to which group members share space affects the ways in which they will use an LDGA. In the case of the two groups that we studied, we found a correlation between the sense of personal space ownership and control over group awareness information in the space. With a stronger sense of personal space ownership, putting awareness information in explicit shared space was preferable. In the situation with a very loose sense of personal space ownership, the display was useful when integrated into the resident space.

- Group size – With the smaller, more tightly-coupled workgroup, people were comfortable sharing low-level personal information, such as their presence and schedule information. Such information was not only inappropriate for the larger group, but also deemed to be not of interest to group members in general.
- Location of display – The degree to which the display was public affected the type of information that was desired and deemed appropriate. With the Awareness Module, people generally posted very high level, almost "official" information that was likely to be of broad interest. Such posts were usually not of a very personal nature, pertaining to research or business pursuits. In contrast, the Semi-Public Display, located in a more intimate space, often contained information of a more casual and personal nature such as information or questions unrelated to work, and information about daily activities.

We examined these dimensions specifically in these early design explorations in this body of research, and our findings regarding their influence and importance in the design and use of LDGAs influenced our later design work for IM Here (Chapter 5), as well as our analyses of the NASA MERBoard (Chapter 6) and other LDGA systems (Chapter 4).

CHAPTER 4

THE FIVE FACTORS FRAMEWORK FOR LARGE DISPLAY GROUPWARE ADOPTION

In designing and deploying large display groupware and through the analysis of other large display groupware, we have observed that one of the greatest challenges in this domain is that of adoption. Too frequently, LDGAs fall into a state of disuse after their deployment, even when designed for tasks and activities of potential value to the workgroups for which they were deployed. As in all groupware systems, lack of critical mass for large display groupware leads to the perception of underuse, and therefore the perception of a poor cost-benefit ration for users. We observed that this problem seems to occur particularly frequently where large display groupware is concerned and sought to understand specific challenges that these types of displays face in their integration into group work practices.

4.1 Fundamental Differences Between Large Display and Desktop Groupware

In his seminal CSCW article, Grudin outlined a number of challenges for the successful creation of groupware applications [Grudin 1994]. At the time that he developed this categorization of challenges, groupware existed primarily in the form of desktop systems. We believe that while the challenges put forth by Grudin are of great relevance to groupware on large displays, differences between large display groupware and conventional desktop groupware yield different adoption phenomena. At the time his article was written, groupware existed primarily on desktop computers, entailing certain basic assumptions about how users would interact with groupware. While the design and deployment challenges that the article identified still hold true for large displays, large displays naturally afford different perception and interaction for users than desktop machines. The inherent properties of large display systems distinguish them from desktop applications, heightening the existing challenges and presenting new ones. Some of these properties are:

- *Form factor* – The physical size of large displays affords different types of interactions and visibility. Unlike desktop groupware, large display groupware is viewable from a greater distance and multiple users can view and interact with them simultaneously. As a result, their size and visual impact affects how users perceive and want to interact with them.
- *Public audience and location* – Large display groupware is usually located in shared space; the fact that these displays are generally more public than desktop monitors affects the amount and type of attention that users direct toward them. Additionally, interactions with the large display are often more visible and less private than interactions with desktop groupware.
- *Not in personal workspace* – Because large displays are usually located outside of an individual's immediate personal workspace, users interact differently with them than with groupware that resides on a desktop machine they use for several hours a day. Specifically, users may be less willing to spend time exploring and figuring out how to use large display groupware than groupware that exists in their personal workspace.

- *Not individually owned*— Large display groupware applications are generally regarded and treated as a group resource; they carry less of a sense of personal ownership and responsibility for use and content than users feel for a personal desktop groupware client; this difference affects the extent to which people use the applications, and the ways in which they interact with the content.

4.2 LDGA Adoption Survey Study

We conducted a study involving three different groups: a) researchers working on LDGAs b) members of workgroups in which LDGAs were deployed, and c) salespeople for a corporation that produces large displays and LDGAs. Our goal was to identify common factors affecting the success of adoption of these applications in terms of their use and integration into workgroup interactions. Our study entailed face-to-face interviews, telephone interviews, and observations of nine systems that had had varying success in being adopted into normal workgroup tasks. In addition to assessing the use of our own applications, we conducted extensive studies of other large display groupware systems; this exploration has entailed interviews and observations of several external large display systems. We sought to explore systems that were in real use and had already been deployed with varying degrees of success. Our method for studying external systems involved open-ended interview discussions with researchers working on large display groupware applications and members of workgroups in which large display groupware applications were deployed. When possible, we conducted these interviews onsite and in person with the participants in our study, in combination with informal observations of the system in use. When face-to-face interviews were not possible, we conducted telephone interviews. We geared our conversations towards participants' personal experiences and observations regarding their perceptions of the systems' use and value within the workgroup, as well as their own personal use of the systems when applicable. Much of the information that we collected in these conversations consisted of anecdotal descriptions of use and personal accounts that have not been reported or analyzed in other individual evaluations of these same systems. Based on these accounts of use as well as the knowledge we have gleaned in developing and evaluating systems, we are able to formalize several critical factors in the success of large display groupware [Huang, Sue, & Russell 2003, Huang, Russell & Sue 2004, Huang *et al.* 2006].

4.2.1 The Notification Collage

This research system, developed University of Calgary is a nearly WYSIWIS (What You See Is What I See) media space that support lightweight workgroup awareness, communication, and media sharing [Greenberg & Rounding 2001]. Users use desktop clients, often on secondary monitors, to post sticky notes, webcams, photos, web page thumbnails and other media; these items appear on other users' clients and large display in shared space (Fig. 4-1). Users can arrange the media items spatially as desired in their individual client space without affecting other users' clients or the spatial arrangement on the large display.

Figure 4-1. The Notification Collage [Image courtesy of Saul Greenberg]

The Notification Collage was well-integrated into group interactions, frequently used for quick synchronous group conversations, sharing of media, and longer-term reminders, queries and to-do lists. This success can be attributed in large part to the low effort required to use the system. The fact that users add and manipulate content via a desktop client means that users do not have to leave their personal workspace to interact with the system. The system starts automatically on users' desktop machines, removing interaction steps on the part of the user as well the cognitive task of remembering to turn it on. Additionally, there is a strong match between the system's functionality and the workgroup's practices. The mixing of social and work interaction, spontaneous group conversations, and frequent sharing of digital media and information are an important part of the work environment in the group for which the system was deployed; the Notification Collage supports all of these interactions well and flexibly. Interestingly, the existence of the persistent desktop client that contributed to the success of the Notification Collage also obviated the large display to some extent. Because the content shown on the large display was identical to that on the desktop clients, people often did not use the large display projection. When turned off, users rarely saw reason to turn on the large display for ambient awareness because the use of the second desktop monitor was sufficiently ambient. Turning on the large display required effort and responsibility on the part of users who did not perceive additional benefit from having it on.

4.2.2 MessyBoard

Carnegie Mellon University's MessyBoard (Fig. 4-2) system supports similar functionality to the Notification Collage; users interacting with desktop clients can project various media items to a large projected display in shared workspace [Fass, Forlizzi & Pausch 2002]. Many MessyBoard items are group-editable, allowing for synchronous and asynchronous collaboration and authoring.

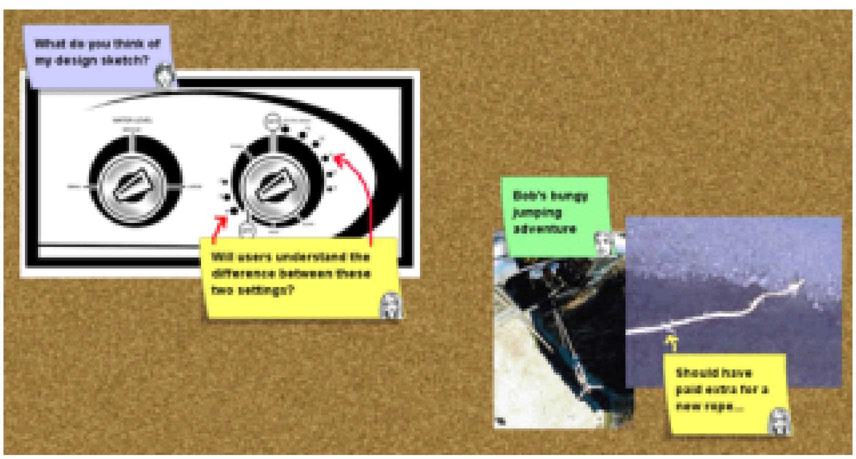

Figure 4-2. MessyBoard [Image courtesy of Adam Fass]

MessyBoard was deployed to several groups, including the MessyBoard developers' own workgroup. While MessyBoard's interactions were simple, at the time of our study the system did not have a simple installation process. This deficit proved to be a significant barrier; because some of the workgroup was not using the system, it was of less value to those who were using it because there was less content and fewer people to interact with the content. Because the large projected display was visible even to workgroup members who had not installed the system, however, it provided value to the entire workgroup. Like many systems we examined, MessyBoard's deployment was characterized by strong novelty use after the initial deployment, followed by sporadic use punctuated with periods of high usage. Users found that email was better for some tasks because it was targeted and different people could have their own copy of a document to work on. However, for such tasks as meeting scheduling, in which it was better to maintain a single copy of an artifact, MessyBoard provided a superior solution and thus was used regularly. Although the use of MessyBoard as a tool for group document authoring was sporadic, this behavior may have been because people's need for intense collaboration was similarly sporadic. Often around an important deadline, the workgroup appropriated MessyBoard to support periods of synchronous collaboration because it could be used as an "instant warroom," and ensured that people were working on the same version of a document.

The deployment of MessyBoard employed several strategies to encourage adoption. The groups to which MessyBoard was deployed often had personal connections to the researchers, and the researchers took advantage of these connections to foster excitement and encourage use. The researchers conducted training sessions to expose the groups to the technology. They also targeted specific individuals to use the system; they selected people who had the greatest need to convey content and whose information would be of general interest to the workgroup, such as the administrative assistant.

4.2.3 Plasma Poster

Designed and deployed at FXPal, Plasma Poster is an electronic bulletin board that allows users to post and view items of interest to large displays in shared spaces in the work environment (Figure 4-3) [Churchill *et al*. 2003, Churchill *et al.* 2004]. Unlike the Notification Collage and MessyBoard, Plasma Poster does not use a desktop client as output; postings therefore are viewable only on the large shared displays. Users can post items to the Plasma Poster via email or through a web form. Because of these characteristics, Plasma Poster content revolves more around announcements and events and is generally of longer-term interest than the more transient and informal items that appear in the somewhat more synchronous and WYSIWIS Notification Collage and MessyBoard applications. Although item posting occurs on users' desktops, the output display is still interactive; users can leaf through the postings, which are shown one at a time on the display. Additionally, users can email items to individuals in the workgroup using the large display.

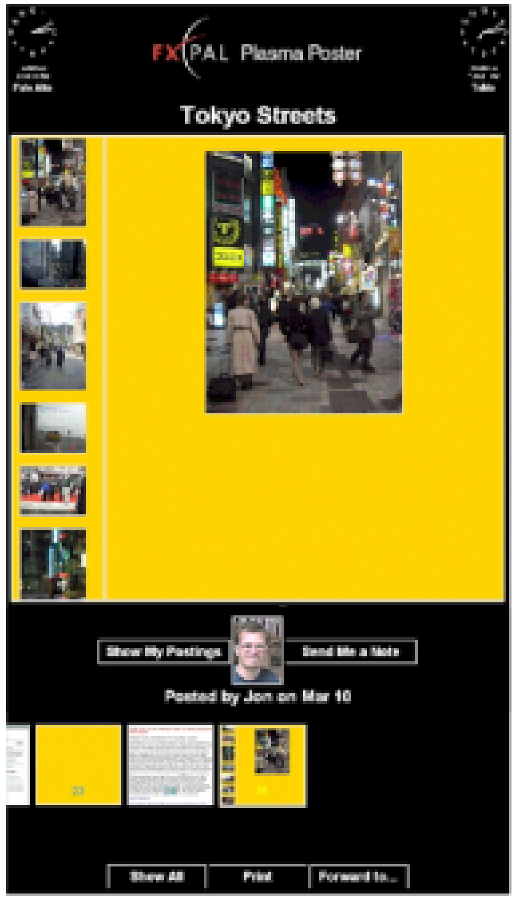

Figure 4-3. Plasma Poster [Image courtesy of Elizabeth Churchill]

Early deployments of Plasma Poster in office environments exhibited a pattern of high initial novelty use followed by a sharp dropoff. Unlike many other systems, however, Plasma Poster's use began to climb after the early drop. This steady improvement can be attributed in large part to having strong champions for use. When other workgroup members ceased to use the system, a handful of dedicated users, including the researchers on the project, continued to keep the content fresh and interesting, thus providing information for the workgroup that helped the workgroup understand the system's potential value, and creating the perception of steady use. Fostering the perception of regular use by the group encouraged other workgroup members to post information because they felt it would be going to a dynamic system that was being well-used by the rest of the group, rather than a system with little content and few users. Although only a small number of workgroup members were actually submitting content at this time, their devoted use of the system helped to maintain its value and eventually encouraged wider use by the workgroup. The system also helped to encourage the perception of use by making interaction with the board visible to users even when they were not in its direct vicinity through the ability to email postings. When users emailed an interesting post to a colleague, the colleague who received the post knew that it was an instance of Plasma Poster use, contributing to the perception of the tool's integration into workplace interactions.

Additionally, as for many other systems, low-barrier interaction that was well-integrated into existing tasks fostered use. Users who submitted content almost always used the email interface to send items to the displays, rather than going to the web submission form. Because the email interaction was more lightweight and less cognitively taxing than visiting and filling out a web form, and because emailing colleagues to share items of interest was already practiced, sending content to the board via email was natural for users.

4.2.4 BlueBoard

Blueboard, developed at IBM's Almaden Research Center, was designed to facilitate informal synchronous collaboration using a large, touch-sensitive plasma display (Fig. 4-4) [Russell & Gossweiler 2001]. The system's functionality includes a digital whiteboard that allows freehand drawing and writing, a proprietary web browser, and access to individual BlueBoard data repositories. Using an RFID badge reader, users can swipe their ID cards to log into the system, giving them access to their own personal data repository on the board. When a users log into the system, small photographs of themselves called “P-cons” appear on the side of the screen; users can drag documents on top of P-cons to put the documents into that user’s repository.

Figure 4-4. BlueBoard

The BlueBoard faced significant challenges in its deployment to the workgroup. It was frequently used as a display device with which people would project laptop content when giving talks, but the actual BlueBoard collaboration software was less successful. Users especially appreciated that they could easily email files to themselves from the board, but ultimately found little reason to do so because the board did not fully support most common file formats. One of the primary difficulties that users had with the software was that it supported proprietary applications; the web browser and whiteboard applications were not integrated with commonly used applications on personal machines. This mismatch made it such that data products produced on individuals’ machines, where they did most of their work, usually could not be used on the BlueBoard with full editing and authoring capabilities. Users also expressed the opinion that they were not comfortable standing around in front of the display to collaborate, and that it was often easier for small groups to gather around someone’s laptop than to work together on the board. Migrating laptop content to the board required additional interaction on the part of the users that did not fit well with the informal nature of their collaboration, and the benefit of the larger screen was outweighed by the necessary effort. There was as well some conflict in how users perceived the display; while most users considered it to be a tool for synchronous collaboration, at least one user wanted to use it as an ambient information display as well. This user tried to share screenshots of recent projects with the workgroup on the display when it was not being used interactively and found that people would often switch the display off when no one was in front of it.

4.2.5 MERBoard

NASA's MERBoard [Trimble, Wales & Gossweiler 2002, Tollinger *et al*. 2004] collaborative display was built to support scientists and engineers involved in the Mars Exploration Rover (MER) missions and its design was inspired by that of the IBM BlueBoard. MERBoard (Fig. 4-5) provides many of the same basic functionalities as BlueBoard and also offers tools designed specifically to support MER mission tasks. When a user logs into the system, he has access to his own personal MERSpace repository with which he can retrieve and save documents. MERBoard also provides extensive whiteboard capabilities for freehand drawing and authoring. The system supports the use of many common desktop applications and file formats. Additional tools support tasks specific to the MER missions, most notably the SolTree planning tool which allowed scientists to visualize possible courses of action for the rovers.

Figure 4-5. MERBoard

An early pre-mission deployment of the system for mission scientists offers interesting insight into the balance between general and specific functionality and the power of visibility of use. Although the system was deployed to mission scientists, engineers who saw the system in use unexpectedly began to use the system after seeing its potential value for their own tasks. Because much of the functionality, such as the whiteboard capability, was designed to be general and not constrained specifically to scientists' tasks, the MERBoard was highly successful during this deployment. In the mission deployment, the value of some general functionality led to an unexpected difficulty. When the system was not being actively used, the display was used as a clock that showed Mars time for the locations of the rovers, Pacific Time, and Greenwich Mean Time. This information was of general importance to all members of the workgroup and as a result, people were hesitant to appropriate the display for small group interactions for fear of depriving the entire group of a resource. As with the BlueBoard deployment, many people found it required less effort to simply collaborate around someone's laptop and that the larger display did not offer enough benefit to small groups to warrant the extra effort necessary to display work artifacts on them. The exception to this was the use of the SolTree tool, which small groups frequently used on the MERBoard. SolTree supported a critical task for scientists and was only available on the MERBoard, making MERBoard invaluable because workarounds using laptops or desktop terminals were inferior.

4.2.6 iRoom

The Stanford iRoom project and its component and affiliated projects comprise a testbed and an architecture for the creation of interactive room environments Johanson, Fox & Winograd 2002, iLoft]. In our conversations with researchers involved in the iRoom project, we focused primarily on the ways in which the large displays in various deployments of their interactive workspaces had been used. iRoom has been used to create several such workspaces, but we looked primarily at a setup in a conference room of their computer science building and several setups in classrooms. iRoom tools, such as PointRight [Johanson *et al*. 2002] and MultiBrowse [Johanson *et al*. 2001] allow users with laptops to control the large displays from their personal machines and share browser content on their laptops on the large displays.

Figure 4-6. The Stanford iRoom [Image courtesy of Stanford]

Interestingly, although the setup in the Computer Science Department was in a shared conference room and its functionality was available to members of the department, researchers reported that the only people who made ue of the interactive technology were the people involved in the project. The interactive aspects of the large displays in the classroom setups, however, were frequently used and in high demand. Students in the classes conducted in these augmented rooms made use of the interaction between laptop content and large display content during class discussions, and professors instructing the classes requested the technology in their classrooms. We believe that students enrolled in these classes had greater motivation to use the interactive large displays than the workgroups who used the computer science conference room because there was a tight integration between the classroom discussion and the use of the boards for displaying content of relevance to the class.

4.2.7 SMARTBoard

Unlike the other projects described above, the SMARTBoard is a commercial whiteboard tool rather than a research application. As such, SMARTBoards have been deployed in a wide variety of settings from business to education, for collaborative and single-person use. Providing a broad range of functionality from simple electronic whiteboard tools, the ability to capture and project, and remote real-time collaborative editing capability, SMARTBoards are considerably more generic and flexible than the systems described above. Several of the LDGA projects we describe here run on SMARTBoard hardware and make use of SMARTBoard software and applications.

In conversations with marketing employees of SMART, we discovered, as expected, that adoption of SMART's displays and the various functionalities available on them varied greatly among deployment sites; our informants spoke of boards that served as primary workplace tools as well as others that had fallen into disuse. As might be expected for a general-purpose tool that has become ubiquitous in workplaces, the situation of the tool greatly affected its use, with boards deployed in conference rooms used more frequently for presentations and projection, while those in offices were used as whiteboards. The aspect of deployment that seemed to have the greatest effect on use and adoption in general among SMARTBoard deployment sites may have been training sessions that SMART offered for customers. For some deployments, SMART provided not only initial training sessions but also refresher courses or sessions to demonstrate additional functionality to promote further use of their tools. Interestingly, our informant observed that the customers were often familiar with the functionality that he demonstrated, but that the demonstration encouraged further use of these functionalities even though the users were already aware of them. In these cases, the repeated exposure helped users to realize the potential value of the functionality, possibly by helping them to envision how the tool might be of use to them, and by making them more comfortable in their knowledge of how to use it.

4.3 The Five Factors Framework for LDGA Adoption

Our research uncovered five important factors that were common across many of the systems we studied. Each stemmed from the four common characteristics of LDGAs that we identified, as described in Section 4.1. The factors are a combination of technical and social issues that influence system design as well as techniques for deployment that affect adoption and usage. While we did not find that these factors applied universally without exception to all of the systems that we studied, we found that they emerged as important aspects of system adoption across many or most of the systems. The resulting framework of adoption factors aims to provide high-level design guidelines for the design and deployment of large display groupware systems, as well as a set of heuristics for analyzing the adoption of such systems.

4.3.1 Task Specificity and Integration

The value and usefulness of large display groupware must be more immediately evident than for conventional groupware because users may spend less time exploring and experimenting on a large display. Systems should address a workgroup's existing practices or tasks and offer a clear benefit over existing methods for addressing those tasks.

In many LDGAs, the specificity of the tasks involved was crucial to the adoption of a tool that seemingly supported general collaboration practices. Systems introduced for the sake of promoting specific collaboration or information sharing tasks generally were more successfully adopted than those introduced for general collaboration purposes. Tools designed or deployed to support specific tasks were more likely to be successful if they either deployed for a task for which their use was critical, or a for a task whose content itself was critical to the user. Whenever possible, systems should be integrated into existing workgroup interactions, rather than suggesting new types of collaboration or information sharing that workgroups do not currently engage in using conventional groupware, face-to-face collaboration, or other means. Users are unlikely to attempt to discover a large display groupware system's value on their own if they are not already aware of some potential benefit it offers to them. The system's design and the method of deployment, such as training sessions or demonstrations, should make the system's value immediately evident. Systems introduced for the sake of promoting specific workgroup tasks generally were more successfully adopted than those introduced for general collaboration purposes.

For these critical tasks, the systems needed to present a clear and immediately apparent benefit over existing methods for accomplishing the same task. One of the most common mistakes we observed in the design of large display collaboration applications was the assumption that the increased screen real estate and ability to save digital artifacts would be sufficient motivation for users to migrate their collaboration to the display from a laptop, conventional whiteboard, or other tool. More space and the ability to save documents are desirable but unnecessary for many types of informal collaboration, however, and users generally did not expend the necessary effort to collaborate on the large display application if there is no need to do so. The SolTree tool on MERBoard provides an example of how task-specific functionality led to good use of a system for collaboration—in addition to being physically amenable to group work, MERBoard offered support for a necessary task that was superior to collaboration using other surfaces or displays.

4.3.2 Tool Flexibility and Generality

Large display groupware applications that support general practices encourage further adoption by new users and new groups or for novel tasks. Although integrating a system with specific tasks is important for allowing users to recognize the system as valuable, flexible design allows it to be further integrated into work activities.

Although large display groupware introduced for specific tasks or tightly integrated with important tasks often have adoption success, we have also observed the value of broad and flexible collaboration support in their design. Most successful systems provide support for a breadth of different practices that people employ to collaborate, even though the systems were deployed to support specific tasks. In many cases, successful systems were designed and built to support a broad range of tasks, but were *deployed* with the purpose of supporting specific critical tasks—the researchers working in the project showcased uses of the system that addressed tasks and interactions that were specific to the workgroup, thus making its value immediately evident. Once users began to use the system and understood its value, they often appropriated the tool for additional purposes if its design was flexible enough to support their new needs. One example of this occurred in the deployment of the Awareness Module; because users had expressed a need to know high level work status information about their co-workers, we deployed the system to them, introducing it as a tool through which they could broadcast information about publications, ventures, and product commercializations. Early use centered around milestone information items, but people later used it for more informal purposes, such as to announce when they would be absent from work. Because the system's deployment for a specific and necessary task allowed users to see its value, they began to use it. Once they learned how to use it and its potential for information sharing, users appropriated it for an unexpected purpose, and the flexible design allowed them to do so.

A flexible tool that is deployed to support a specific task may be also appropriated for other tasks as people realize the tool's potential. A system that supports a broad set of collaborative practices may be used beyond its intended purpose. In the case of the MERBoard's pre-mission deployment, a tool designed and deployed to help visiting scientists collaborate was appropriated by teams of resident engineers because it provided them with general tools for creating shared digital artifacts as well as an easy method of distributing documents among users.

4.3.3 Visibility and Exposure to Others' Interactions

The interaction of others demonstrates usage and value because the form factor and public nature of these applications can make user behaviors highly visible. Making actions observable helps promote the perception of use, which encourages the perception of benefit to the group and may make other users less hesitant to interact with the system.

Users often discovered a potential use for the system after observing another user interacting with the display. Because these systems are highly visible, interaction by one user can serve as both instruction and “advertising” for the system to others in the group. In some cases, certain features existed of which users were aware, but they were exposed to the value of the features after observing others making use of and deriving benefit from them. For example, the highly visible use of the MessyBoard for scheduling meetings prompted people in the group who had not previously used the system to install it so that they could use it to participate in the scheduling as well. Although they were previously aware of the MessyBoard’s ability to facilitate such interactions, it was not until they saw others using it that they realized it was a better tool for the task than email.

In addition to the physical visibility of interactions on large displays, making usage visible in other ways, especially those that are observable when people are not physically near the display, is beneficial to adoption success. For example, the item forwarding feature of the Plasma Poster existed in the interface for approximately three months before it received use. Though the feature was highly visible and people were aware of it, users did not perceive it as useful until they saw others using it. Through seeing people forwarding items and possibly from receiving forwarded items, users began to use that feature regularly. One key to the success of this feature was that when users received the emails, they knew that someone had used the large display system to generate the message, thus promoting the knowledge of the system’s use. Because large displays are perceived as more public than desktop systems, the exposure to others’ interactions on LDGAs can influence usage and the perception of value.

4.3.4 Low Barriers to Use

Barriers to use must be low so users can quickly discover value because large display groupware is less amenable to trial-and-error and has a lower frequency of use than desktop groupware.

It is important that users be able to interact successfully and easily with the system early in their usage in order for the system to be adopted into normal tasks. Systems that require significant time to install or configure, have time-consuming steps to initiate use, or have functionality that is not readily visible tend to find small audiences or a drop in usage after the initial deployment. Although all of the systems we examined met with positive feedback from the workgroups regarding the technology and the functionality, many users simply did not find that the benefits outweighed the inconveniences that the system imposed. These inconveniences included not only interaction steps designed into the application, but also factors more inherent to large display use, such as having to go to the physical location of the display, having to stand up to work with the display, the discomfort of writing on a glass surface, or dealing with visual parallax on a plasma screen or shadows on a projected display. All of these issues add additional barriers to large display groupware use that do not exist in desktop groupware. It is therefore extremely important that the design of the system allows users to derive benefit without extra interaction steps or high overhead because the use of a large display application already entails additional overhead. For this reason, several of the systems that offered whiteboard capabilities were underused for small informal synchronous collaboration, because gathering around a laptop, while not ideal for collaboration, was sufficient and required no additional steps.

Systems that allow users to interact with the display through the use of a desktop client were generally used more frequently than those that allowed interaction only at the large display because permitting desktop interaction helps alleviate some of the barriers inherent to large displays. Even in these cases, simple interactions yield better use: Plasma Poster users have the option of posting information via a web form or an email address. Because email is perceived as quicker and easier than going to a form and filling it out, it is often used to post, while the web form is not. Similarly, although MessyBoard users install the system onto their desktop machines, the lack of a simple setup process discouraged potential users from installing it during its early deployment.

4.3.5 Dedicated Core Group of Users

Advocates and a core set of users early on help others to perceive usefulness and reduce hesitancy to use the system stemming from their form factor and location.

With all groupware applications, achieving critical mass is crucial to adoption [Grudin 1994]. Because large display groupware systems are generally less amenable to exploration and experimentation than desktop groupware, they are more likely to fall into disuse soon after deployment. In many of the systems we studied, we found that use was aided by having a dedicated core group of users early in the deployment. This group, which often included researchers working on the project, used the system regularly and encouraged usage by others after the initial burst of “novelty use” died down. Especially for systems in which user-submitted content was crucial for success, continued use by the core group ensured that displays remained dynamic and content fresh rather than stale. The perception that displays were used and viewed encouraged further adoption into everyday use by a wider audience. Additionally, the core group advocated others' use by directly encouraging others to use the applications. In several applications designed to share user-submitted items, core users encouraged coworkers to post information onto the displays that they had previously emailed to others. This encouragement was positive feedback to the senders of the information and helped lower initial hesitancy they felt about interacting with a new system, both technically and culturally.

The recruitment of influential users is another strategy that contributes to the success of large display groupware system. In the cases of the Notification Collage and the Awareness Module, use of the system by the workgroup manager attracted other people to the system and increased the value of the content. Targeting users such as managers, administrative assistants, and others whose interaction is of general interest to act as champions for the system is beneficial to system adoption.

4.4 Continued Research on the Five Factors Framework

The framework described above is the product of a broad study of existing LDGA systems and is not intended to be universal or absolute. In the following chapters of this dissertation, we will describe research that we have conducted to apply the framework to the design and analysis of specific large display groupware systems. We use this design and analysis work to refine the framework to be more general and encompassing as we increase our own understanding of LDGA adoption. While the results and understanding gained from these projects allow us to improve the robustness of the Five Factors Framework as an explanatory tool and set of design guidelines, we stress again that the framework is intended to express patterns and general phenomena of large display groupware use and adoption, rather than to serve as a set of prescriptive rules that guarantee successful large display groupware applications.

In parallel to this work, we have continued discussions and kept abreast of findings of other researchers working in the realm of large display groupware as a way of collecting further data with which to gauge the coverage of the framework. Several additional LDGAs, such as Proactive Displays [McCarthy *et al*. 2004] and Dynamo [Izadi *et al*. 2003, Brignull *et al*. 2004] have been deployed and evaluated since we first formulated the Five Factors Framework, and the Plasma Poster has been further deployed and evaluated [Churchill *et al*. 2004]. The observations and experiences of researchers involved in these projects seem to correlate well with the results of our study, and with the Five Factors Framework. Notably, Churchill et al's evaluation presents several "factors for success" specific to the design of the Plasma Poster and its adoption in the workplace. Many of the findings the specific findings that they present correspond well with factors in our framework. For example their emphasis on the value of "goodness of fit" corresponds to our factor regarding task specificity, "low effort, flexible, control" corresponds to low barriers, "simplicity of form and function" is related to our notion of task generality and flexibility, and "synergistic displays" relates to our factor regarding the visibility of others' interactions. A brief deployment of Dynamo revealed similar findings specific to that system that support our framework. The researchers provided these findings as design guidelines, and they include an emphasis on general and adaptable functionality that are not over-designed for specific tasks, as well as the use of intuitive interactions to reduce initial barriers to use.

Although the findings of these recent projects do not correspond exactly to our framework, it is reassuring that the results of evaluations of specific systems provide support for our general framework based on a survey of systems. Additionally, it is encouraging that evaluations conducted by researchers other than ourselves reveal findings that reinforce ours.

CHAPTER 5

APPLYING THE FIVE FACTORS FRAMEWORK TO LDGA DESIGN

In order to assess the value of the Five Factors Framework for large display groupware applications, we have applied them as general design and deployment heuristics for a novel LDGA. In undertaking the IM Here design project at IBM Almaden Research Center's USER group, we sought not only to improve workgroup communication through the use of large displays, but also to apply our specific findings from previous work to foster the adoption of a newly-introduced LDGA [Huang, Russell & Sue 2004]. In designing and deploying the IM Here system, our motivations for the content, function, and tasks stemmed from the group's work practices and communication breakdowns as well as existing research on informal communication and instant messaging (IM). Specific interface design decisions and our deployment tactics, however, were tightly guided by the framework. The factors served as guidelines for building and introducing IM Here in the 24-person workgroup.

5.1 Motivation for Instant Messaging in an LDGA

Informal communication is an important part of many workplace tasks. Instant messaging is valuable for facilitating informal communication between workgroup members for such purposes as scheduling, negotiating availability, and maintaining awareness [Nardi, Whittaker & Bradner 2000]. However, much of the work people do takes place away from their personal workspace [Whittaker, Frohlich & Daly-Jones

1994], limiting the value of IM for these tasks. We sought to extend IM access beyond people's PCs, making IM available in other places where work occurs. We aimed to discover new value by breaking the current paradigm of personally-owned IM and introducing IM as a shared public resource.

We developed the IM Here system (Figure 5-1) as an awareness and communication tool that takes advantage of IM for lightweight interactions and large-scale displays for their walk-up-and-use nature. The system uses the large, highly visible form factor to promote group awareness of upcoming events. The large display also emphasizes the fact that its IM capabilities are a *shared* resource for the workgroup. To help facilitate informal communication in the workplace, we aimed to create a publicly available IM tool that would reside on a large display in a shared workspace, extending the value of IM beyond the personal machine.

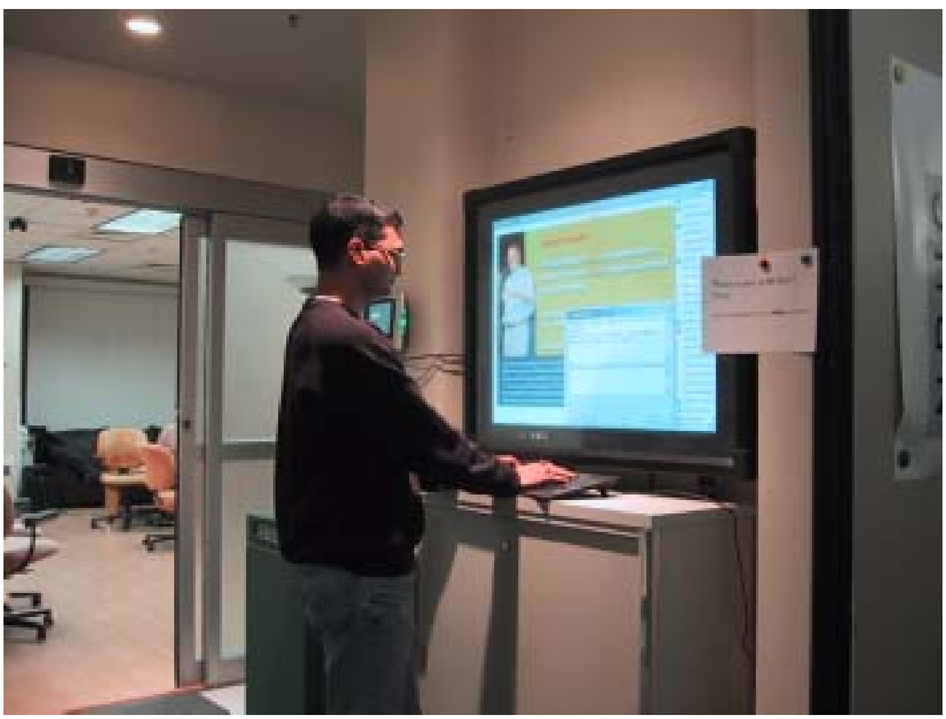

Figure 5-1. IM Here deployed near a conference room.

5.1.1 Not All Work Takes Place in the Personal Workspace

Studies done by Whittaker *et al*. show that people spend much of their workday engaged in work activities that do not take place at their desks [Whittaker, Frohlich, Daly-Jones, 1994]. During this time, people engage in informal communication that facilitates work tasks. These tasks include formal and informal meetings, collaborative activities, and other activities that require people to work outside of their personal workspace and away from their PCs.

5.1.2 IM Helps People with Work Tasks

Studies of IM in the workplace by Nardi *et al*. illustrate IM's value as a tool to enable informal, lightweight communication between co-workers [Nardi, Whittaker & Bradner 2000]. They point to the affordances of IM, such as its casual and non-distracting nature, as well as its immediacy and visual persistence as reasons why it is preferable to other channels, such as telephone or email, for certain work tasks. Her studies demonstrate the utility of IM to facilitate "outeraction" – communication not for conveying informational content, but to facilitate further interaction. Examples of outeraction for which IM is used are negotiating availability and scheduling. Supporting outeraction when people are away from their workspaces was a key motivator for the design of IM Here.

5.1.3 The Need for Access to Communication in our Workplace

Observations of practices within our workgroup provided further motivation for group-accessible IM in shared spaces. For instance, despite the ubiquity of networked laptops, workgroup members often did not take these machines with them when they worked outside of their personal workspace, especially for spontaneous or unplanned work. Contacting people outside of their immediate vicinity required that they leave the current work area to find people or return to their personal workspaces to communicate using their machines.

We also observed that people commonly needed to contact others during or before collaborative tasks or group events. For example, we noticed one particular behavior associated with a common room often used for meetings, gatherings, and planned or impromptu collaboration. Before a scheduled event, the organizer, host, or speaker would notice missing parties or a poor turnout, thus prompting him to run about the building wing knocking on office doors or trying to locate or recruit people. This practice took the organizer away from the event venue and also reduced the amount of time available for the event. Behaviors like this further suggested that providing ways for people to contact others from shared workspace could be valuable to the group.

We also observed an ineffective use of email as a medium for announcing events that suggested another potential use for public IM. The organizer of the event typically would send an email announcement to the group several days before the event, and then another immediately preceding the event to let group members know that the event was starting. This second email often was not noticed by recipients in a timely fashion. The visible alert and immediacy of IM seemed potentially valuable for this type of communication.

5.2 The IM Here System

The IM Here application consists of two primary components: The IM Here Event Display provides lightweight information about upcoming events and announcements; the IM Here Messaging Client allows users to send instant messages to workgroup members from the display in a walk-up-and-use fashion (Fig. 5-2). Together, these two components comprise an LDGA that provides awareness information to the workgroup in its passive state and also affords quick connections and conversations through overt interaction. The system was deployed near the entrance of a conference room that is frequently used for formal and informal meetings, social gatherings, talks, and spontaneous or planned collaboration (Fig. 5-1). The area where the system resides is well-trafficked both by people using the conference room as well as passersby.

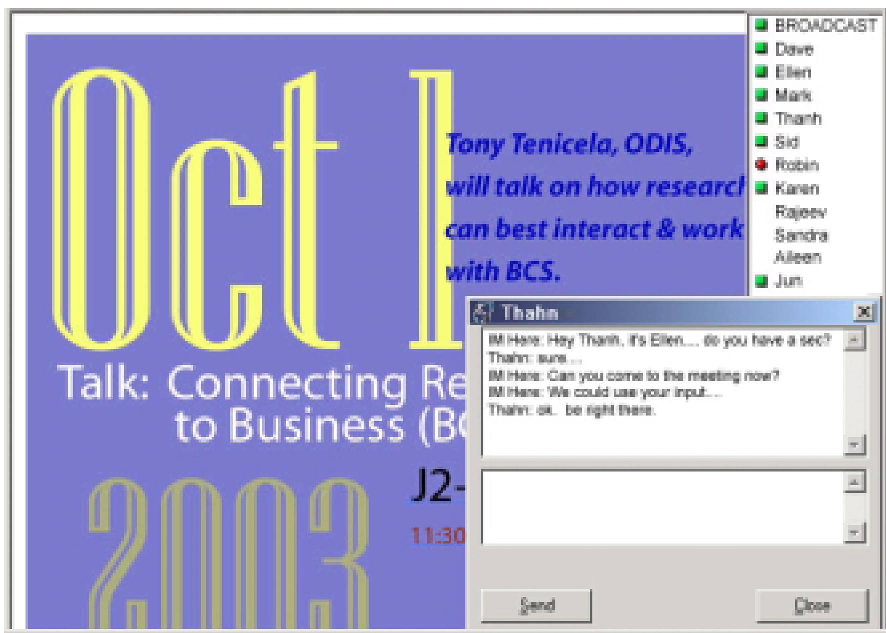

Figure 5-2. IM Here in use for messaging with the Event Display on the left and the Messaging Client on the right with a messaging window open.

5.2.1 IM Here Messaging Client

The IM Here Messaging Client provides a publicly accessible channel for low-barrier instant messaging. It is interoperable with the Sametime instant messenger client and was built using the Sametime IM toolkit [Sametime]. The compatibility with Sametime allows users of IM Here to communicate with users of Sametime, the primary messaging client used within in our workgroup. In its passive state, the client provides persistent awareness cues in a public location. The contact list for the client lists workgroup members and uses Sametime's status cues beside the names to indicate whether group members are available (green square), idle (yellow diamond), busy/do not disturb (circle with a slash) or not logged on (no indicator). The persistently visible list provides value by supporting lightweight awareness about presence and availability [Isaacs *et al*. 2002]. For messaging, IM Here functions similarly to conventional IM clients with a few key differences:

Broadcast – The Broadcast feature of IM Here allows users of the kiosk to send a message to everyone on the contact list who is logged onto Sametime. This feature was motivated largely by our observations of people running around to knock on doors or sending mass emails directly before a group event. Broadcast allows people to send messages to the group quickly and easily, and in a way that is both immediately visible and lightweight to the recipients. Providing users the ability to mass-IM the group creates the possibility of overwhelming the group with unsolicited, irrelevant messages. However, because group members are generally judicious with other forms of mass communication or have some idea of what is socially appropriate for announcing to their community, we expected this to be the case as well with IM Here broadcasts. Rather than building in technical barriers to prevent unnecessary broadcasting, we opted to explore whether social norms and practices would prevent abuse of the feature.

No Login Process– All messages sent from the IM Here kiosk to Sametime users appear to come from the account called "IM Here" rather than from the Sametime username of the sender because IM Here has no login or authentication process. The design decision not to require authentication provides senders and recipients with three major benefits. First, it keeps use barriers for the senders very low, making the system truly walk-up-and-use. Users can quickly tap on a recipient's name and start typing messages; the interaction is immediately available with little or no overhead. Another option was to use a method of automatic identification such as active RFID tags, or a badge-swipe. However since badging in requires another step and group members do not already carry active tags, either method would have added an extra barrier to use.

Secondly, as most IM clients only allow a single account to be open on one machine at a time, eliminating the user's need to log into IM Here prevents the closure of existing Sametime sessions that might be open on the user's desktop or laptop machine. We expected that most interactions on IM Here would be transient and brief and people would not want to lose existing personal sessions. Many IM users treat their personal clients like voicemail, leaving them open even when they are not present. Our observations of our group and previous messaging research have shown that some users send "sticky note" messages even when they know that the recipient is not present [Dourish & Bly 1992]. Messages such as, "Can you IM me when you get back to your desk?" are a common use of IM. It would be inconvenient if personal sessions were closed every time people used IM Here for quick messaging.

Finally, the fact that the recipient of messages sent from IM Here sees the messages as coming from the user "IM Here" rather than the sender's normal Sametime login provides context to the recipient about the sender's situation. The recipient knows that the sender is in a public location, not in personal workspace, possibly not alone, and likely not in that location for long. This bit of social context helps the recipient mediate her messaging, possibly by avoiding confidential or personal subject matter or saving involved discussion until later.

Though the use of the dedicated IM Here account provided the above three benefits to both senders and recipients, having an anonymous IM user presents potential problems. Does the lack of an identifying account name confound the recipients of IM Here messages? Would “vandals” take advantage of the anonymity to masquerade as other group members or send prank messages? When using communication channels without built-in explicit identification of the initiator, such as phones without caller identification or notes left on office doors, people generally make clear who they are. For messaging using IM Here, we wanted to explore whether the social practice of identification would develop or carry over from other channels. Additionally, since prank-playing and identity forging are generally considered unacceptable in workgroup phone or paper note use, we also expected that they would become unacceptable in regular IM Here use after the system novelty had worn off. We opted to try to take advantage of social norms and people’s standard communication practices rather than building in additional technology and a burdensome login process.

5.2.2 IM Here Event Display

The Event Display takes advantage of the affordances of large displays for promoting awareness of various upcoming events that are of relevance to the workgroup in general. The display presents graphical and text postings regarding announcements or events on a continuous cycle; each posting is shown for a default of 25 seconds. The content of the posting ranges from formal (an invited speaker talk in the auditorium) to casual (an informal afternoon gathering because a colleague has baked a cake for the group). Content for the Event Display is generated using a web-based interface accessed on a personal machine. The form allows users to enter information about the event such as the title, description, date, location, and expiration date; a posting is automatically generated from this information and put into the cycle. The posting remains in the cycle until it expires.

For this design, we placed the primary responsibility of maintaining content on an administrator who regularly created postings from email announcements and the company web page. Although users were welcome to post their own items and occasionally did, our focus was not on getting users to post, nor did we want to rely on getting user-submitted content for value. Our focus was instead on the IM interactions and adoption, while the events served as a way of making the display attractive and providing value in the passive state. Similar systems whose focus is on presenting user-submitted content offer lessons on how to foster this, especially as pertains to the low barriers for input [Agamanolis 2003, Brignull *et al*. 2004].

5.2.3 Balancing Public and Personal in IM Here

The tasks IM Here supports have public and personal aspects that we attempted to address in our design. Announcements and event postings are clearly for group awareness, but they also serve the purpose of being informative to individuals. The contact list provides awareness to the group but also informs personal IM interactions. IM itself is generally a personal interaction, but the large public display makes it less private than using one's personal client. The use of a physically large display encourages the perception of the system as a public tool [Tan & Czerwinski 2003], and because so much group work takes place in the space, we wanted to encourage it as a shared tool. Our design attempts to keep IM conversations more personal by positioning IM windows low on the screen, making the interaction in the user's field of vision and less visible to others

(Fig. 5-2). Because of the nature of the space and the tool however, we did not expect that users would conduct private discussions using IM Here; maintaining a sense of personal interaction in the design was more for user comfort and appropriateness than for stringent conversational privacy.

5.3 Applying the Five Factors Framework to IM Here

The factors greatly influenced our design process and deployment plan for IM Here. We sought to provide value to users through the communication channel and interactions of the system, and the factors served as guidelines in designing these interactions and introducing the system.

1. Task specificity and integration – IM Here was demonstrated to the workgroup not as a general purpose communication tool; rather it was presented as a solution for people who were running talks and meetings or collaborating within the space. We made potential benefits concrete by illustrating how the system could help users avoid having to run around to people's offices or go back to their own office to call or IM someone. This served to make the value explicit and immediately recognizable.

2. Tool flexibility and generality – IM Here makes use of a general purpose communication tool already in use by nearly all members of the workgroup. It is also easily appropriated as needed because of its public form factor and location in the environment. IM is clearly flexible and IM Here maintains that flexibility even though it was deployed for task-specific purposes.

3. Visibility and exposure to others' interactions – Messages and broadcasts sent from IM Here are easily and immediately identifiable by the recipients as having been sent from that system thus increasing the perception that system is being used.

Additionally, the public location allows others to observe it in use. Broadcasts for events are especially visible because many people receive the information being sent.

4. Low barriers to use – The system has no authentication process so the functionality is persistently accessible. Additionally, users do not need to engage in any interaction or do any navigation with the interface to access the functionality. There is also no overhead for seeing the event postings or contact list statuses. To initiate a conversation, users need only to touch on a name on the buddy list or click on it using the mouse, and begin typing into the messaging window that appears. IM Here acts similarly to existing clients so there is almost no learning curve for IM users. Its interoperability with Sametime also means that people do not have to install anything on their machines in order to receive IM Here messages and broadcast announcements.

5. Dedicated core group of users – In addition to the researchers, we explicitly recruited a small key set of enthusiastic group members to use it and encourage use. We selected people who frequently had a need to communicate from the common room including an intern who was collaborating with several researchers and a researcher who was in charge of the weekly research talk in that room.

5.4 Deployment Results

5.4.1 General Findings

We conducted an evaluation during the first six weeks of the deployment of IM Here in our workgroup. During this time we logged IM Here use, made informal observations, and conducted casual, open-ended interviews with 11 group members. The user population consisted of 24 researchers, engineers, and administrative assistants who had had varying degrees of experience with large displays and IM. Of the 24 members listed on the contact list, 13 of them described themselves as regular Sametime users who would be logged on at least one third of their work hours. According to our logs, there were 41 instances of IM Here use over 30 business days. Of these instances, 17 were dyadic conversations ranging in length from 2 to 12 messages, 14 were broadcasts to the group, and 2 were one line messages that required no response. Additionally, there were 8 attempts to start conversations from IM Here that met with no response from the recipient. This is common even in conventional IM, and may be attributable to people not responding immediately or being away from their machines [Isaacs *et al*. 2002, Nardi, Whittaker & Bradner 2000]. Within the 41 instances of use, there were a total of 165 messages transmitted. A graph of usage over the six weeks (Fig. 5-3) shows that the instances of use remained fairly steady while the number of messages spiked initially before leveling off in the third week to approximately 20 messages per week (4 per day). Non-broadcast messages were sent to a total of 17 different people. Because there is no login process for using IM Here, we could not accurately assess the number of people who sent messages from the system, but based on the transcripts, we can surmise from context and self-identification that at least 8 people sent messages from the system.

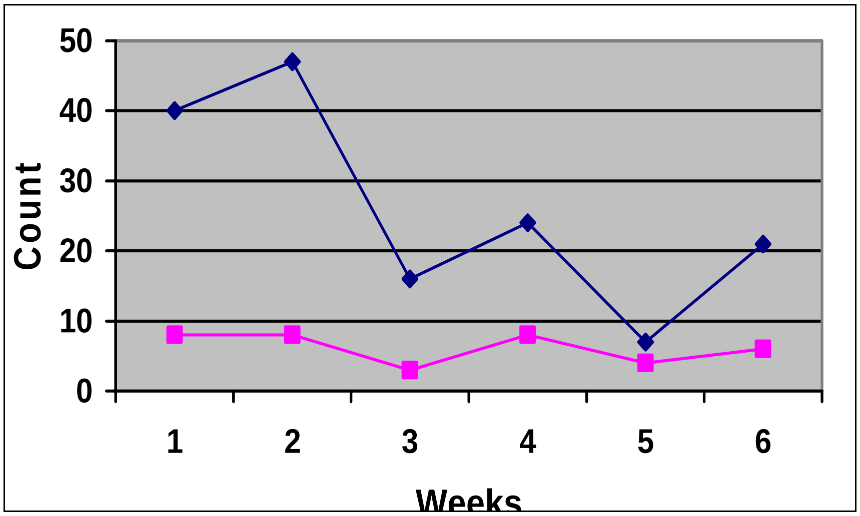

Figure 5-3. IM Here use over a six-week evaluation period. The lower graph shows the number of instances of use. The upper graph is the number of individual messages transmitted

We found the usage numbers to be promising; IM Here is used on a daily basis, and our post-deployment follow-up interviews suggested that significant portion of the workgroup has sent and received messages using it. Because of the anonymous nature of use and the fact that users did not always identify themselves when sending messages, it is impossible to determine exactly which and how many members of the workgroup actually used the system to send messages. The number of broadcasts corresponds roughly to the number of scheduled groupwide events for the common room. Although the numbers of messages and conversations are perhaps lower than for a desktop IM client, the system is intended for brief, walk-up-and-use exchanges on an as-needed basis rather than continuous use throughout the day by dedicated users. Considering the size of the workgroup and context of use, the extent of the use suggests that IM Here was successfully incorporated and integrated into everyday work activities.

People’s reactions to the system based on our observations and interviews were generally positive. They found it to be convenient and useful, especially because of its proximity to the common room. Group members who had not sent messages from the system usually attributed this to lack of occasion to do so rather than not seeing value in IM Here. Most people who said they had not sent messages from it qualified that they would likely do so in the future, especially for broadcasting talk announcements.

5.4.2 Addressing Initial System Motivations

Logs of conversations and broadcasts also showed that IM Here addressed our initial motivations for making IM a group-accessible tool in shared space. The following brief exchange illustrates the value of IM Here when people are engaged in tasks outside of their personal workspace:

1:41:06PM IM Here: *We're here now, Mark and Sid.*

1:41:11PM Naomi: *OK*

Naomi, Mark, and Sid are scheduled to meet in the conference room to work. Because IM Here is close by, Mark and Sid use it to let Naomi know that they there and waiting for her, saving them the trouble of physically trying to find her or returning to their offices to message her. Again, because IM Here has no login process, messages sent from it appear to come from the account "IM Here."

The next transcript demonstrates the use of the system for accomplishing the "outeraction" tasks described by Nardi [Nardi, Whittaker & Bradner 2000]. In it, Karen uses IM Here because it is close by and therefore the most convenient way for her to contact Carl:

4:32:10PM IM Here: *it's karen... where are you?*

4:32:20PM IM Here: *going back to my laptop... don't reply here*

4:32:22PM Carl: *im in a conference call right now*

4:32:25PM IM Here: *still???*

4:32:29PM IM Here: *you're yakking it up!*

4:32:34PM IM Here: *could you IM me when you're done?*

4:32:47PM Carl: *yes!!! I promise*

4:32:53PM IM Here: *:) ok*

Karen was mobile in the workplace and used the system for scheduling further interaction, and, as in the previous transcript, negotiating availability.

In this next instance, we can again see the convenience of having the system situated by the common room. A user went to the room thinking there was a tea there, and did not see anyone preparing for the event.

3:55:09PM IM Here: *Is there teatime today?*

3:55:15PM Janet: *no*

3:55:28PM IM Here: *Ooops. I guess we'll wing it then.*

3:55:37PM Janet: *thx*

The user used IM Here to message Janet, the coordinator of the usually weekly event, to check if it was happening. Upon finding out that no one was slated to bring in food for the event, the user decides to “wing it” – the group’s jargon for foraging for available snacks in the office to serve at the tea. The user obtains the information about the event in the place where it is relevant.

The use of the Broadcast feature was similarly valuable for group events in the common room. The act of broadcasting the group before weekly scheduled events, such as a lunchtime research talk and the tea, became a regular practice for advertising these events immediately before their start.

3:56:15PM: IM Here Broadcast: *Moon cakes now in [the common room]*

Broadcasts like this one provided information and served as a more timely and visible reminder than email. They also prevented legwork on the part of the host. One user mentioned that broadcasts were especially effective for him because he was not diligent about maintaining his calendar and would otherwise have missed some of the events. This user expressed a preference for IM Here broadcasts over last minute email announcements because, “email is not a notification system.” Another user found the broadcasts useful, but did not like that they arrived in an IM window because they appeared at first to require interaction.

5.4.3 IM Here for Awareness

Many users mentioned the value of IM Here in its passive state because of the IM status information and event postings. Nearly all users reported that they checked it regularly; one even said that he had changed the route he took to his office in the morning so he would pass by the display. Another user mentioned checking the IM statuses every morning on the way to her office to make sure she was not “the last one in” of her close colleagues. One user requested mirrored content on additional displays throughout the workspace. Some requested alternate posting methods for the Event Display, using email or IM to input; we plan to include a lower barrier posting mechanism in future iterations. Although we relied on the administrator to create postings, 8 of the 47 postings came from users.

5.4.4 Emerging and Unexpected Uses for IM Here

IM Here was originally conceived as a tool to allow people working in the shared space to send messages and initiate communication with people working on their personal machines. Our logs showed that IM Here was occasionally of value for allowing people to access people in the shared space, especially for the purposes of obtaining information about that space:

11:11:53AM Dave*: Dear passerby -- Can you tell me if [the common room] is scheduled from 1- 2PM? (I'd look at the server myself, but I can't get there from here for some weird reason...)*

11:14:51AM IM Here: *1 to 2 PM today looks open. 2 to 2:30 is booked.*

11:15:06AM Dave*: Thanks! (I'm at 2 - 2:30) -- BTW - who are you?*

In this instance, Dave messages the IM Here kiosk from his office, asking passersby to check RoomWizard (the information appliance that displays conference room schedules [O’Hara, Perry & Lewis 2003]), which is located nearby. From the timestamps on the messages and the fact that Dave received no response to his final message, we surmise that someone happened to walk by and notice Dave’s query, checked the RoomWizard and walked off after responding to the initial request. Again, the location of IM Here provides value because of its volume of traffic as well as its situation in an area in which important events and information reside.

Another unexpected use of the system arose from the juxtaposition of the IM Here Event Display and the Messaging Client. On a few occasions, users cut and pasted event postings into IMs or broadcasts. The system provides a means of obtaining awareness information as well as a way to pass that information along to others easily.

5.4.5 Social Norms for Mediating IM Here Use and Abuse

IM Here did not encourage prank playing, despite the anonymity built into its design. Since its deployment, only one instance of use might be construed as a "prank" taking advantage of anonymity. As expected, this joke usage occurred in the first few days of the deployment and can likely be attributed to novelty. By the use of nicknames in addressing the recipient, it is likely that the prank message was meant more as a joke among friends than to annoy a colleague anonymously. We conclude that due to social norms, group accessible anonymous IM did not encourage abuse of anonymity for the sake of intentionally irritating colleagues in our workgroup.

IM Here's anonymity also was not a problem for message recipients. According to our follow-up interviews, recipients felt that IM Here users identified themselves in a timely fashion. Additionally, they believed that because IM Here was accessible only by the workgroup because of its location, anonymity did not pose a problem. Some believed it might be a problem if IM Here were more accessible by outsiders.

Broadcast was also used judiciously. There were no instances of broadcast being used for pranks. Users expressed the opinion that broadcasts were relevant and effective reminders rather than annoying or “spam-like” because people were careful in selecting what and when to broadcast.

5.4.6 IM Here and Display Size

In developing this prototype and evaluating it, we were investigating the question of how people would use and respond to an informal communication tool on a large display in a work hotspot. We did not specifically seek to answer the question of the how its use would be different from a similar application running on a conventional monitor, and therefore did not create an experiment designed explicitly to test the effects of display size. The results of our deployment and evaluation do suggest, however, that the fact that the application was running on a physically large display affected the use and perception of the display to some extent. Use cases, such as that described in section 5.4.4 in which a user working in personal space sent a message to the IM Here display, show a potential benefit of the display size. The visibility of a large display lends itself to this type of use, in which it is important that the information in the environment grabs the attention of the passersby. Additionally, if the user in his office had known that the message would only be shown on a small display, he may have been less likely to have sent it in the first place. Work by Tan and Czerwinski provides further evidence that large displays lend themselves to public use and viewing; their findings suggest that display size has a strong effect on viewers’ perception of the display as a shared or public resource [Tan & Czerwinski 2003].

5.4.7 IM Here and Mobile Devices

Our study also did not explicitly examine conditions under which people used mobile devices to communicate as opposed to IM Here. In our follow-up interviews, participants did not mention using IM Here as a substitute for mobile communication devices, nor did they refer to any instances in which they explicitly chose to use a mobile device instead of IM Here. Although much of the communication that we witnessed in IM Here might have been possible to achieve using mobile devices, we still posit that the use of IM situated at a particular location embodies an experience that is qualitatively different from the use of mobile phones that influenced the use of IM Here. Findings by Nardi et al suggest that IM is regarded as less intrusive and more lightweight than phone calls, and people may therefore have been more inclined to send a message using IM Here than make a phone call. This seems particularly true for the non-urgent purposes for which IM Here was typically used, including the purpose of “herding” people for an event.

The use of instant messaging on mobile devices did not seem to be a common practice in the workgroup at the time of this deployment. Locationally opportunistic conversations, such as that between Carl and Karen, as described in 5.4.2 suggest that having the information tool in the environment may prompt communication that the user might not otherwise have chosen to initiate. The instance in which Dave sends messages to the shared display in 5.4.4 also suggests that there is a difference between attaching the communication to a space or an environment, as opposed to putting the communication on the body.

5.5 Reflections on Public IM for Workgroups

We believe that the use of group accessible IM in shared workspaces has potential benefit as a supplement to existing channels for informal workplace communication. IM Here demonstrates this value by allowing users to have convenient means for quickly establishing contact with colleagues whose locations are not nearby and possibly not known. Previous work has shown that awareness cues built into IM clients allow for opportunistic conversation as colleagues log on and become available [Isaacs *et al*. 2002, Nardi, Whittaker & Bradner 2000]. IM Here allows for this type of opportunism as well as *locational opportunism* by being in the environment. Additionally, the location of the system *where work happens* allows users to communicate with others in the place and context in which the conversation is likely to be most relevant to their task.

5.6 Reflecting on the Value of the Five Factors Framework for IM Here

Using the five factors as guidelines for our design and deployment helped to make the system appealing to users and promote adoption. Although it would be difficult to prove the direct effects of using the factors to inform the system, observations and conversations with users indicated that decisions we made based on those factors contributed to IM Here's adoption and integration into regular work practices. The visibility of others' interactions and encouragement by the core set of users increased the perception that the tool was being used. The flexibility of the IM medium in combination with the demonstration of its value for specific tasks allowed users to see the potential use and benefits of the system immediately. Users responded very positively to the low barriers for use, citing the lack of login as greatly enhancing the system's convenience, with many users stating that they would not have used the system if they had had to log in. Although the system's content and functionality stemmed from practices and characteristics that we observed in a specific workgroup, the general design guidelines provided by the Five Factors Framework yielded strong visibility of the system's use, fostering the important perception of use among the workgroup members, and making the system's potential value apparent to the target users.

CHAPTER 6

EVALUATING A LARGE DISPLAY GROUPWARE APPLICATION WITHIN A DISPLAY ECOLOGY

In January of 2004, the National Aeronautics and Space Administration (NASA) landed two unmanned vehicles on the surface of Mars for the purposes of collecting scientific information regarding the terrain, composition, and atmosphere of the planet. The Mars Exploration Rover (MER) mission has continued for the past 20 months, with the two rovers, Spirit and Opportunity, continuing to transmit data to Earth as they traverse the surface.

In the previous three chapters, we described our experiences in designing and evaluating large display applications. These chapters looked primarily at how individual users or groups of users interact with a single shared display, with a focus on the adoption success of applications. In this chapter, we describe a year-long field study of the NASA MERboard, a large display tool designed by NASA researchers specifically to support the activities of scientists involved in the MER missions. In undertaking this study, we aimed to look beyond users' interactions with the display, and focus more broadly on the role of the displays within the context of the work environment and collaborative practices of a unique workgroup, and how the MERBoards related to other technologies, devices, and displays employed by users. Although evaluating adoption success is still a major part of this study, this in-depth study allowed us to develop a broader, more ground-up picture of the use of a large display groupware tool in a complex context of use. In terms of authenticity and length of deployment, number of deployed systems, number of users, and complexity of functionality, the MERBoard offered us the opportunity to conduct an evaluation that was considerably more in-depth than our previous evaluations of large display applications. In this chapter, we present our findings from this study, and frame its use within our in-depth understanding of the context in which it was deployed.

In this chapter, we present the results and analysis of a year-long field study of the MERBoard and the MER mission display environment in which we uncover an ebb and flow of large display use as collaborative tasks and practices evolve over time. Our findings suggest that:

- Large interactive displays are valuable as interactive support for exploratory tasks for which procedures are ill-defined; as tasks become proceduralized, these displays can be useful sources of ambient information.
- Tasks migrate among displays within a display ecology as tasks and collaboration styles change; this migration is deeply influenced by the other displays in the environment and their respective affordances.
- Evaluation should be based on how well and flexibly the entire ecology of displays supports work tasks, rather than a simple measure of use or disuse of individual displays or applications within the environment.

In the following sections of this chapter, we present background information on the MER missions, MERBoard, MER display ecology, and related research. We then present our findings regarding the adoption evolution of use of several MERBoard functionalities within the context of the display ecology. We follow this with a discussion of the implications of our findings for design and evaluation of large interactive display systems and multi-display environments.

6.1 Overview of a Complex Work Environment

In this study, we were given the opportunity to conduct a long-term field study of the NASA MERBoard, developed by researchers at the NASA Ames Research Center. Unlike the briefer examination of the MERBoard that we included in the Five Factors Framework study, this research study was done after it was deployed for actual use in the MER Missions and reflects the MERBoard's entire duration of use from pre-mission through the end of the co-located mission. Much of the data we gathered came directly from interviews with the users. The study we conducted of the MERBoard in the broad survey study described in Chapter 4 was done before the mission deployment, and therefore focused on the use of the MERBoard in pre-mission simulation trials and training sessions, and the data we collected was from the researchers and designers of the MERBoard based on their observations of the trial use.

The actions of the rovers as well as the data that they collect are guided by mission scientists and engineers, and the mission is based at NASA Jet Propulsion Labs (JPL) in California. To coordinate their activities, scientists and engineers employ a variety of tools for collaboration and information sharing. In the group workspaces designed specifically for the MER Missions, shared displays, including large projection screens, large interactive plasma displays, and shared workstations with multiple monitor setups, are ubiquitous. Together, these surfaces form a "display ecology," in which the uses of individual displays influence the roles of others, despite not having been designed as a unified, seamless system. Of particular interest to us is the MERBoard, an example of an emerging class of pervasive computing technologies comprised of interactive large multi-user display systems (Figure 6-1) [Trimble, Wales & Gossweiler 2002, Trimble, Wales & Gossweiler, 2003]. Although many such systems have been designed, deployed, and studied in a variety of settings in recent years, the NASA MERBoard system, designed and deployed specifically to support MER Mission science tasks, is particularly interesting in its complexity and the extent of its deployment in authentic work settings.

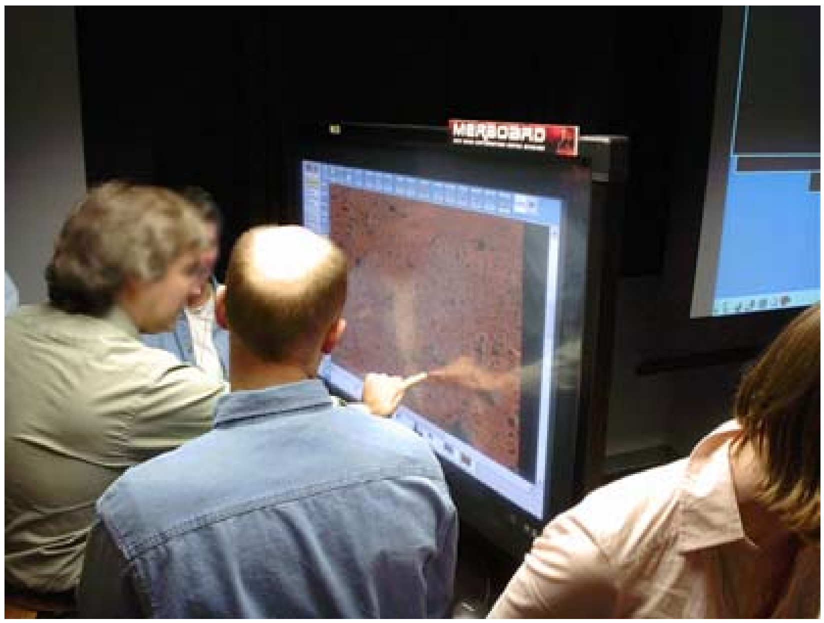

Figure 6-1. Scientists discussing a terrain image on the MERBoard.

Unlike many other large interactive display systems, MERBoards were deployed to support specific, time-dependent work tasks of real users. MERBoards were integrated into a fast-paced, round-the-clock and often hectic work schedule to support necessary tasks; this is in contrast to many systems that have been deployed primarily in research or test environments as supplemental support for collaboration, rather than a primary medium for accomplishing work tasks. Additionally, many MERBoards were deployed in parallel, with 18 of the displays in use at JPL during the initial months of the mission, whereas other research prototypes have often been single instances of the technology or deployed in small numbers. Finally, unlike many other large display groupware systems, MERBoard has been integrated into a work environment that contains many display alternatives, including several other large display options (Figure 6-2, Figure 6-3). All of these factors led us to investigate not only how users interacted with the MERBoard, but also address the greater issue of the role of interactive large display groupware within highly dynamic, complex display ecologies.

Figure 6-2. **MERBoards, projectors, laptops, and workstations in the work environment.**

Figure 6-3. Scientists use projection screens and multi-monitor workstations to view and discuss data.

6.2 Background on MER Missions

The gathering of scientific information on the MER missions has entailed highly dynamic procedures, especially during the “nominal mission”- the initial three months following the rover landings. Working on a 25-hour cycle (the length of a “Sol”, or Martian day), teams of scientists and engineers would receive, process, and analyze downlink data from the rovers and Martian satellites, decide the next course of action for the rovers as well as what data should be collected next based on this information, convert these decisions into sequences of instructions for the rovers, and send this information to the rovers via the data uplink. Each of the steps in this cycle was highly collaborative, and required significant coordination between groups of collaborators working on various steps of the cycle, as well as among group members working together on a single task.

Scientists and engineers generally had distinct responsibilities, although there was considerable collaboration between them. The mission science teams were composed of five theme groups: Atmospheric Science, Geology, Minerology and Geochemistry, Soil and Rock Physical Properties, and Long Term Planning. These groups were responsible for the scientific aspects of the mission, such as analyzing the data gathered by the rovers, deciding what further data goals and exploration should be pursued, and determining at a relatively high level what course of action the rovers should take. In contrast, engineers were responsible for the more tactical aspects of the mission, including determining the rovers' exact sequences of action, controlling the instruments on board the rovers, sending the information to rovers, and collecting the downlink data.

In addition to the distinct responsibilities of the scientists and the engineers, there were also several other differences between the two groups that affected collaboration. For example, the engineering teams consisted primarily of NASA staff and contractors who were resident at JPL; many of them had collaborated previously on other missions. In contrast, while some of the scientists were also NASA employees, the majority came from other institutions all over the country and were working together for the first time. Furthermore, from the standpoint of the engineers, the tasks in which they engaged bore resemblance to their tasks for previous NASA missions. For the scientists, the tasks that they engaged in were highly novel and bore considerably less resemblance to the scientific activities of other NASA missions. For these reasons, work relationships in the science teams were more dynamic and practices less established and proceduralized than those of the engineering teams. This was particularly true in the nominal mission, thus affecting the ways in which collaborative technologies were used and adopted.

During the nominal mission, all scientists working on the mission were resident at JPL, with all of the science theme groups for each mission co-located within large science assessment rooms. Within these rooms, each theme group had its own area, each with a MERBoard, several workstations, and two projection screens. Additionally, there was a MERBoard and a pair of projection screens in the front of the room used for presentations and meetings. At any given time during the nominal mission, several dozen scientists were present in the space; this number decreased steadily after the end of the nominal mission. Engineers worked in teams in several other smaller spaces at JPL, including Mission Control and Sequencing areas. These rooms had different configurations of displays, with at least one MERBoard and one projector; some had multiple of each.

During the extended mission that followed the nominal mission, some scientists returned to their home institutions and began to work remotely; science activities were distributed across JPL and other laboratories, while the engineering tasks continued to take place at JPL. As the mission was further extended, science collaborations became increasingly distributed.

Prior to the start of the mission, many of the scientists and engineers participated in a set of mission simulation exercises called the FIDO (Field Integration Design and Operation) trials. During the exercises, the teams engaged in simulated mission activities, on a compressed time cycle. They were also trained on and exposed to the tools and systems that they would be using during the actual mission, including the MERBoard.

MERBoard hardware consisted of 50” 1600 x 900 resolution plasma screens with touchscreen overlays. Developed specifically for the anticipated needs of MER scientists, MERBoard provided several functionalities to support collaboration and work tasks

[Trimble, Wales & Gossweiler 2002, Trimble Wales & Gossweiler 2003]. In this research, we focus on a subset of applications (Table 1) and how their use evolved in the context of the multi-display environment. The functionalities presented below represent a cross-section of the applications available on MERBoard, spanning passive to interactive value, providing both freeform and structured support.

Table 6-1. Summary of the MERBoard functionalities focused upon in this study

Functionality	Intended Users	Tool Summary
SolTree Tool	Scientists	Tool for building graphical tree structures to represent possible next actions for the rovers. Plans were visualized as nodes, paths, and branches with annotations to keep track of information associated with each plan. Plans, also called “SolTrees,” could be saved, and later modified
Whiteboard	Scientists, engineers	Tool for authoring documents and images with stylus for freehand drawing and writing, graphical tool palette, or a keyboard as input. Content on personal machines could be put into a shared directory and accessed on MERBoard. Whiteboard content could be saved and retrieved. A tabbing mechanism permitted switching between multiple boards.
Mars Clock	Scientists, engineers	Full-screen, persistent clock that displayed the current Earth time at JPL, Mars time for the Spirit rover, and Mars time for the Opportunity rover.
Schedules	Scientists, engineers	MERBoard could be used to access and display CIP (Collaborative Information Portal) and other schedules, which showed the daily schedule of deadlines, meetings, and events.
MERSpace User Directory	Scientists, engineers	MERSpace was a folder-based directory system that could be accessed from personal machines and the MERBoard. Users had individual document repositories in MERSpace that others could access.

6.3 Related Research

Our evaluation of the MER mission display ecology was designed to complement an earlier observation-based evaluation of the MERBoard conducted by the designers of the system [Tollinger *et al*. 2004]. This study examined the knowledge and data management practices surrounding document creation and use on the MERBoard, whereas our study sought to focus more generally on users' perspectives of the tasks, tools, and collaborative practices over time, as well as the interplay among the many situated displays in the ecology.

Several other interactive multi-user display systems and multi-display environments have been designed for the purposes of supporting work tasks or collaborative work. Like MERBoard, systems such as BlueBoard [Russell & Gossweiler 2001] and Tivoli [Pedersen *et al.* 1993] offer whiteboard-type tools for collaborating on shared artifacts. Designer's Outpost [Klemmer *et al.* 2001] offers scaffolding tools for the purpose of supporting preliminary website design. Tools such as MessyBoard [Fass, Forlizzi & Pausch 2002] and the Notification Collage [Greenberg & Rounding 2001] support synchronous and asynchronous communication for collaboration. Projects like CoLab [Stefik *et al.* 1997], ARIS [Biehl & Bailey 2004] and iRoom [Johanson, Fox & Winograd 2002] focus on the architecture, system design, and interaction techniques of multi-display environments with a focus on how users can interact across the displays. These systems and environments have been evaluated primarily in laboratory studies, used only in research settings (often the home laboratories of the researchers), or in limited-term experimental trials. While the evaluations of these systems have yielded valuable findings regarding the value and use of large interactive displays for supporting group work [Huang *et al*. 2006], we still lack a deep understanding of what role these systems play in natural work environments over time.

A recent workshop on multi-display environments (both single-user and collaborative) [Hutchings, Stasko & Czerwinski 2005] included position papers that identified common types of multi-display environments [Shen, Ryall & Everitt 2005], as well as technical design considerations for such environments [Inkpen & Mandryk 2005].

We believe our work builds upon the existing research by providing an in-depth examination of how one of these systems is used in context and in real use. Our findings can help better inform the design of such systems and tools by uncovering the evolving use of multi-display environments over time by users who were not involved in the design of the system, and whose work tasks are so critical that they will only use a tool if it provides a clear benefit in helping them accomplish these tasks.

6.4 Study Description

This study was designed as a summative inquiry into the overall value of the MERBoard and other display technologies used in the mission, as well as a reflection upon how the roles and perception of these tools changed over time. The study was designed to complement earlier field studies conducted by the designers of the MERBoard, which focused primarily on MERBoard interaction in the early months of the mission, following their initial deployment [Tollinger *et al.* 2004]. The primary motivation for conducting an evaluation retrospectively, after much of the co-located collaboration had ended, was to understand the overall impact that the displays had on the mission and work activities as a whole; understanding the users' perception of the system on the mission in general allowed us to make design recommendations that are currently being used to influence the design of new iterations of the tool for other NASA workgroups and future missions.

We conducted semi-structured interviews with sixteen scientists and engineers on the MER Mission project, as well as initial background interviews with six NASA researchers involved in the original design and deployment of the NASA MERBoard. Two of the scientist interviews, as well as all of the designer interviews took place onsite at NASA laboratories, while the remaining interviews with scientists and engineers were conducted over the telephone. All interviews lasted between 30 and 60 minutes. Interviews with scientists and engineers took place between twelve and sixteen months after the start of the mission, and were conducted me. I had not been involved in the original design or deployment of the MERBoards, and was otherwise unaffiliated with NASA. The perspective of an uninvolved researcher was intended to provide an unbiased complement to the in-house usage studies that had been conducted by the designers of the MERBoard in the earlier months of the mission.

In the following section we present the findings of our interviews and observations with NASA scientists, engineers, and designers. To arrive at these findings, we performed inductive analysis upon our interview data using open coding [Bernard 2000] to identify patterns and trends. The descriptions of practices and MERBoard uses and opinions on the system we describe were triangulated among multiple study participants, unless we specify that a particular use or reaction to the MERBoard was only reported by a single user.

6.5 The Evolving Uses of MERBoard Over Time

In this section, we present an overview of the use of the MERBoard within the context of the display ecology. Because the functionalities that we examined each displayed some unique uses and patterns of evolution, we break the presentation down by the individual applications, and describe the overarching themes and general implications in the sections that follow.

6.5.1 SolTree

The SolTree Tool is frequently mentioned by MERBoard designers and MER Scientists as the most utilized tool available on the MERBoard early in the mission. Used regularly during approximately the first 70 Sols of the MER missions for planning activities primarily by the Long Term Planning (LTP) theme group, SolTree can be considered the closest to a "killer app" provided by MERBoard (Figure 6-4).

Figure 6-4. The SolTree tool on MERBoard.

This design of a structured scaffolding tool on a shared display surface entails several assumptions; it assumes that the task that it supports will be done by a group of people, rather than an individual. It also assumes that this collaboration will be synchronous and co-located in such a way that a shared visual surface will be beneficial to the collaboration. Additionally, the design of this tool assumes everyday or near-everyday use during the mission, since it was intended to support planning on a Sol by Sol basis. We found that these assumptions did not hold throughout; the nature and timing of the Sol planning task evolved over the course of the mission, as did the type of collaboration used to accomplish the task. The evolution of task and practice eventually caused Sol planning to migrate off of the MERBoard entirely, as the scaffolding provided by the tool and the shared visual surface offered by the large display ceased to fit the task in the later part of the mission. For this reason, SolTree unexpectedly proved to be most effective as a "ramp-up" tool, rather than the steady-state support tool for daily use for which it was intended.

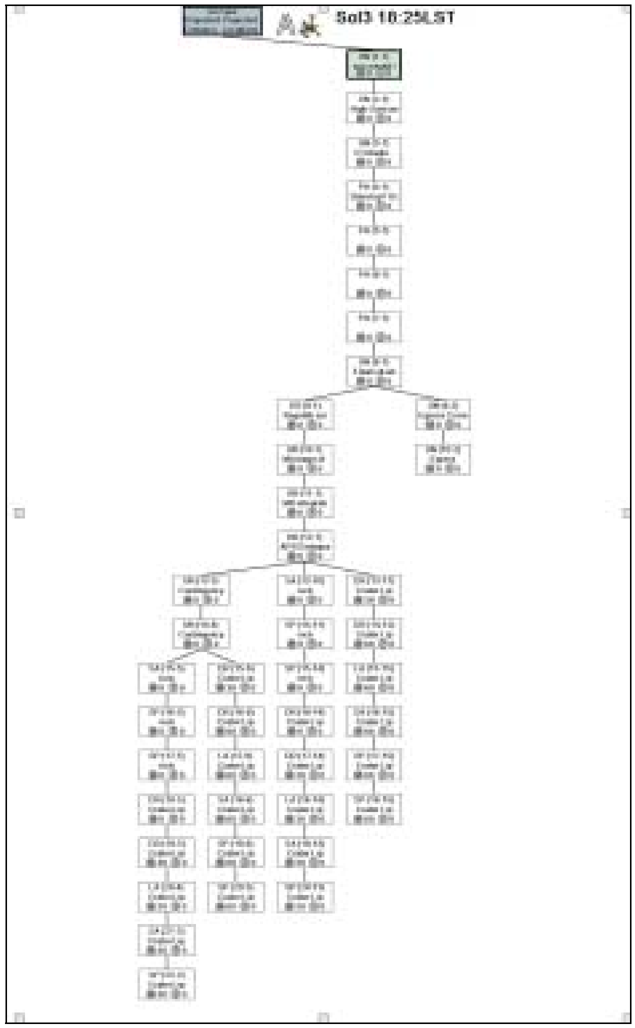

Figure 6-5. An example of a plan visualization created using SolTree on the MERBoard.

Display size and group size: The process of SolTree planning in the MERBoard involved a small group of collaborators, generally between three and a dozen people. It is clear from the scientists' comments that the number of people involved in SolTree planning decreased during the course of the mission. LTP scientists agreed that the MERBoard's physical size was well-suited to the size of the groups involved in these activities early in the mission.

The actual authoring process varied between instances; in some cases, the group would convene around the board, either sitting or standing, while a single person “drove” the display, building the tree based on input from the group (Figure 6-6). As the mission progressed, an individual would often draft a plan alone using SolTree, and then collect other planning scientists around the MERBoard for feedback and editing. The role of the display changed from that of a shared authoring surface that allowed many people to take part in the authoring and decision-making process, to a visual display space for presenting a nearly-finished artifact to the workgroup.

Migration to projection screen for large meetings: Although MERBoard was well-suited for the planning task early in the mission, images of SolTrees were often exported as images or transcribed into PowerPoint for the purposes of displaying them on the projectors during meetings when the plans were being presented to a larger workgroup. The size and resolution of MERBoard simply was not sufficient to make MERBoard a valuable presentation tool for this type of viewing. The migration to projection was difficult, however. Scientists complained of the overhead necessary to convert the SolTree into a format that could be shown on a projector; there was no simple way to integrate a plan created on the MERBoard into a presentation.

Figure 6-6. Scientists collaborating on a plan using SolTree.

Tool structure supports early collaborative work: Most of the LTP scientists appreciated SolTree's ability to keep track of all of the possible branches and options, especially in the earlier parts of the mission. Others praised the fact that SolTree imposed a structure on brainstorming options; it required planners to think down each linear path and consider and annotate all of the possibilities. One user of the tool said that it "forced explicit logic" and required the scientists to consider all possible ramifications. Another scientist emphasized the importance of the tool soon after the rovers landed because the tool "offered scaffolding" for a process that was still new to the scientists and not yet routinized.

Persistence and evolution of plans: Though the general perception of the SolTree tool among scientists is that it was provided as a way to interactively author plans for Rover activities, their descriptions of use illustrate a broader value of the tool as a persistent information display for community awareness. SolTrees were often left open on the LTP theme group's MERBoard even after the planners had completed their planning for the day, simply as a way of maintaining awareness of the planned activities and options, and also as an informal way of making that information available. One scientist described it as a service to others so that they would “absorb it.” The SolTrees were often left visible until someone needed the display for another purpose.

The persistence of the artifact also created continuity from day-to-day between the various LTP leads, particularly as the mission progressed and the planning process stabilized. The SolTrees were not only a data product; they were input for the following day’s planning and a way of getting an incoming LTP lead up to speed on the previous day’s plans. SolTree authoring was sometimes described as an “evolution”, with an existing tree repeatedly being pruned, added to, or otherwise edited based on new data, rather than being created anew in each planning session.

Tasks migrate to other displays as collaboration changes: The planning process evolved during the course of the mission, shifting gradually from unfamiliar and exploratory to familiar and proceduralized. As mission goals solidified, planning became more tactical, and scientists generally confined their planning to the consideration of a few potential options rather than a full-blown exploration of all possible next steps. They were better able to anticipate these steps and their implications and the decision making process became increasingly streamlined.

The method of visualizing these plans evolved as well. Scientists described how the tree-shaped plans with their many-branched possibilities gave way to linear path-shaped plans that often spanned multiple Sols. Because they were considering fewer possibilities, the need to specify all of the possibilities in detail decreased. The “inflexibility” of the tool that forced scientists to specify all of the details of the plans became unnecessary overhead. Additionally, the planning process became predictable enough that scientists no longer needed to create them together; it was sufficient for an individual to create the plan on his own and get it approved by the group later. As a result of this evolution of the task, the group use of the SolTree tool on MERBoard for planning eventually gave way to the individual use of PowerPoint on laptops for creating "Sol Paths." In the transition from MERBoard to PowerPoint, some scientists took the intermediary step of using the freeform whiteboard drawing tool to create plans; this supported the collaborative building of trees, while freeing them from the tight scaffolding of the SolTree tool.

Suggestions for future design iterations: Throughout the mission, the planning process was crucial to science activities, even when it was no longer necessary that the process itself be done synchronously and collaboratively. Even so, group viewing of plans, during meetings or when displayed passively, was important for awareness. Migrating artifacts among displays is one solution for getting around the high overhead of the SolTree tool. Another possibility that some of the scientists mentioned was that of multiple "levels" of detail in the SolTree tool. Having various authoring modes in which different levels of detail were required could help the transition of tools like SolTree from a scaffolding tool for synchronous use to a lightweight, single-user authoring tool that would allow individuals to quickly create plans and display them on the MERBoard.

6.5.2 Whiteboard and Image Display on MERBoard

In contrast to the SolTree tool, the MERBoard whiteboard application was not designed to support a specific task, but rather to provide flexible, *ad hoc* support for collaborative tasks. Even so, the design of the tool reflects some of the same assumptions as the design of the SolTree, namely that the use of authoring tools on a shared display surface would be useful for synchronous, co-located collaboration. The fact that the application was not designed to support any specific tasks suggests that it could be useful for any collaborative tasks that might involve shared authoring of artifacts throughout the course of the mission. As we discovered, however, the tasks for which this use of a shared authoring surface were largely exploratory in nature, and thus clustered primarily in the pre-mission work and early in the mission. The whiteboard evolved from a freeform support tool that helped collaborators with tasks for which procedures were not well-defined to a passive information display, as collaborative tasks became more highly proceduralized and moved off of the shared display space. As with SolTree, the interactive uses of the whiteboard proved to be most valuable for exploratory work, in which the MERBoard served as a ramp-up tool while procedures were not yet routinized.

Flexible support for exploratory tasks: During the pre-mission FIDO tests, scientists and engineers used the whiteboard heavily as a support tool while learning how to operate the rovers. In this case, MERBoard served as a learning tool; it was used by the scientists for creating documentation as the training progressed. MERBoard was a good fit because there was no established procedure for creating documentation within the workgroup, and the whiteboard functionality imposed no structure on the note-taking or resulting product. Additionally, this was the type of task for which having a persistently visible representation of collective knowledge was of value. The whiteboard functionality of MERBoard was also used for brainstorming activities during these tests; MERBoard allowed scientists to do freeform sketches with a group, and save and share the designs. The tool's flexibility was valuable for these types of unstructured preliminary planning activities.

During the actual mission, use of the whiteboard was less frequent and decreased over time. As procedures for accomplishing tasks became routinized and streamlined the exploratory aspects of the whiteboard became less necessary. Scientists' practices and procedures became routinized and the need for *ad hoc* support decreased.

Support for transient information and transitional procedures: Early discussions with designers of the MERBoard seemed to suggest that designers were disappointed with the uptake of the whiteboard during the actual mission, and that few documents were created using it. Discussions with several of the scientists suggest, however, that while interaction with the whiteboard may not have been frequent, many scientists perceived the tool to be valuable to work processes during the mission, with one scientist even calling the tool "imperative" to his work activities.

People rarely chose to save the artifacts that they produced, preferring instead to transcribe them into PowerPoint after the collaboration was finished. It seems possible then that part of the reason the whiteboard was perceived by some as not valuable was because the products created on it were highly transient. Unlike the plans created using SolTree, artifacts created on the whiteboard were not often displayed at the larger meetings, perhaps because of their transient, informal content. As a result, informal presentation of this information was done directly on the MERBoard for small groups of collaborators, and did not migrate onto the projection screens. As described in the SolTree section, the need for the whiteboard arose again during the transitional phase of planning when the group still needed to collaborate synchronously on Sol planning, but no longer needed the tight scaffolding of the SolTree tool.

Lack of use for routinized tasks: In contrast to how the scientists used the whiteboard, the engineers we spoke to made almost no use of it for collaboration. In contrast to the science activities, the engineering activities were more structured and proceduralized in large part because they bore significant similarity to activities from previous missions. The sequencing team, whose job was to create very precise, low-level sequences of instructions to transmit to the rovers, had tools with which they were already familiar that had been designed for the purposes of creating sequences. A lead tactical engineer on the mission spoke of the importance of tools that explicitly supported his tasks, stating that he dealt with “very specific bits of hex code going to very specific places” and that a freeform tool like the MERBoard whiteboard simply would not offer the level of detail that he required. Although he and his team worked collaboratively on sequencing tasks, their procedures and tools were well-defined, and the whiteboard’s freeform support offered no benefit to their collaboration.

The unexpected value of passive image display: While most scientists claim to have interacted little with the whiteboard, many were positive and enthusiastic towards it because one team member frequently used it to display images taken from Mars orbiters, maps, and panorama cameras, with graphical overlays or line drawings that he had created on his laptop (Figure 3). Often, these images were displayed for days at a time, attracting interest and prompting discussion, or even retrieved later in the mission for reference.

The scientist liked that he could “release” information into the environment, rather than displaying it from his personal machine. The large display naturally drew people’s attention; the size and dynamic nature of the board made it “easy to notice changes” when new material was present. The scientist regarded the information sharing as a type of "asynchronous collaboration"; for him it was a way of keeping others informed of his activities, prompting new ideas, and letting his images and ideas "enter the public consciousness" with no effort on anyone else's part. He saw MERBoard as an "easily changed poster board" through which he could convey ideas and be guaranteed that they would receive attention.

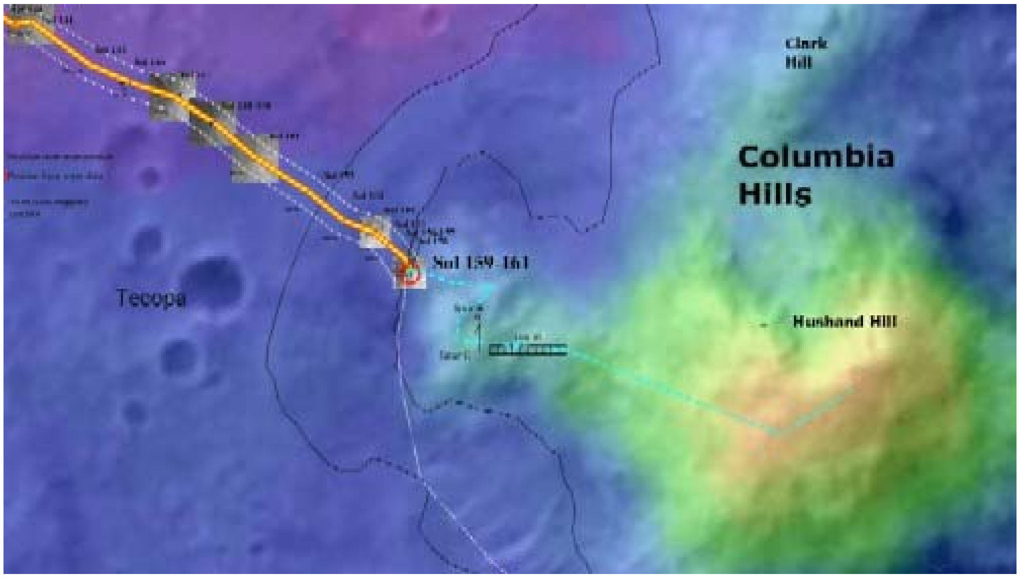

Figure 6-7. An image created by a scientist and displayed on the whiteboard.

Other scientists who wanted to share information preferred to use projectors, not because they felt that MERBoard was inferior for viewing ambient information, but because it was easier to plug a laptop into a projector than post content to the MERBoard. For this reason, projectors were also used to display images in the environment that might otherwise have been displayed on MERBoard.

Although actual paper printouts of terrain data were also used during the mission, printing images was expensive and few had access to use the poster printer. One scientist said that the use of some paper images was eventually "superceded" by the annotated maps that had been posted on the MERBoard.

Although the images were admired and drew interest, scientists stated that there was no conflict or awkwardness about appropriating a MERBoard that was currently showing an image. The author of the images said that people understood that the images were "like screensavers" – non-urgent and displayed as objects of interest, and that it was thus acceptable to hide the image using the whiteboard tabbing functionality in order to use the board for other purposes. There was a "sense that it was public space" and that anything left there was "fair game," as opposed to owned content.

Suggestions for future design iterations: Although there are not many instances of other scientists "releasing" images and documents onto the MERBoard, this scientist's use of it, and its use for passive SolTree display suggest that the community finds value in information being posted as such; their personal dependence on laptops may also suggest that there may be further uses for sharing images without having the display monopolize their laptops. It seems that a more simple and fluid mechanism for releasing information from personal machines to the MERBoard may hold potential for encouraging passive information display activities that scientists clearly found valuable as viewers.

6.5.3 The Mars Clock

Decreasing interaction leads to ambient information display: The Mars clock (Figure 6-8) was a particularly interesting example because of how the ambient display use of MERBoard emerged as the mission tasks and collaboration styles changed. As the mission progressed, the Mars clock became the single most dominant use of the MERBoards used by the scientists. One scientist described the phenomenon as: "When people stopped using the MERBoard, the clock became a useful thing to have up." This statement suggests that it may not have been the case that the clock was perceived a crucial functionality of the MERBoard, but rather that as the other functionalities of MERBoard ceased to be as applicable in everyday work activities, the clock was useful default content for the tool.

Figure 6-8. The Mars clock displayed on the MERBoard.

While scientists generally described the Mars clock as extremely useful, many of them felt the need to “admit” this appreciation of the clock, as they were aware it was not the use that took the fullest technological advantage of a sophisticated and expensive system. Even so, they expressed a preference for keeping the clock ambient in the environment; clocks on their personal machines would take up valuable personal workspace and would be likely to be covered up by other more pressing applications.

Although the use of the clock was entirely passive, the value of this ambient information as a group resource is clear. Even in the later phases of the mission when some of the MERBoards were being used almost solely to display the Mars time, the administrators of the system were flown in to fix them when they crashed.

Social difficulties stemming from uncertainty of use and ownership: Some scientists suggested that people might have wanted to use the MERBoard, but were hesitant to appropriate the board for fear of depriving other group members of the clock. The scientist who frequently posted images using the whiteboard believed that people were considerably more hesitant to hide the clock to interact with the MERBoard than they were to hide the images that he had displayed; once the clock was on the MERBoard, people were less likely to use it than if it had one of his images displayed on it. The scientists may have perceived the clock as being crucial to others' work and were hesitant to interact with the display for their own benefit if it meant inconveniencing the group at large. It also suggests that images were perceived as interesting but non-urgent and non-task-critical, whereas the clock was perceived as potentially in use at any time.

Suggestions for future design iterations: It seems fairly clear that the Mars clock was a valuable piece of information to have in the environment, but it also seems to be the case that many of the scientists were sorry that it was the primary use of the MERBoard. Additionally, while the visibility and persistence afforded by MERBoard was beneficial for the clock, it is not apparent that the clock needed to be on the MERBoard. As designers of MERBoard and several scientists suggested, MERBoard may have seen additional use later in the mission had the clock been available elsewhere in the work environment. Other scientists suggested that the clock gained dominance simply because the other tools available on the MERBoard ceased to be of value as the mission progressed. If this is the case, it may therefore be worthwhile to consider other types of passive content for which the board could be used to maintain its perception of value even when it is not being used interactively.

6.5.4 CIP and Other Schedules

Structured ambient information: Another use of the MERBoard frequently mentioned by mission scientists and engineers was for the passive display of schedule information. Some of the MERBoards in the science assessment area were used for schedule display nearly as much as they were for clock display. An individual's CIP (Collaborative Information Portal) schedule would be posted on the group's MERBoard and then displayed ambiently throughout the day for the entire group's use. These schedules kept group members aware of important events such as satellite passes and meeting times with very little effort. Interestingly, although this use of the MERBoard was as passive as the display of the Mars clock, the general attitude towards the display of the CIP schedule was somewhat more positive. The schedule information was more inherently group relevant, and therefore may have been perceived as supporting collaboration or coordination to a greater extent than the Mars clock, and therefore more in keeping with the original intent of the shared display.

Low-overhead authoring: The sequencing work done by engineers was highly co-located and required tight time coordination, which made awareness of the schedules crucial. The tactical uplink lead engineer used text on the whiteboard tool of MERBoard rather than the official CIP schedule to type schedules directly onto the MERBoard, including times, events, and primary milestones such as the activity plan approval and sequence walkthroughs (Figure 6-9). Schedules were generated daily, either created from scratch or modified from the previous day's schedule. Additionally, schedules were modified as necessary throughout the day by the tactical uplink lead engineer in the event that a particular activity "slipped."

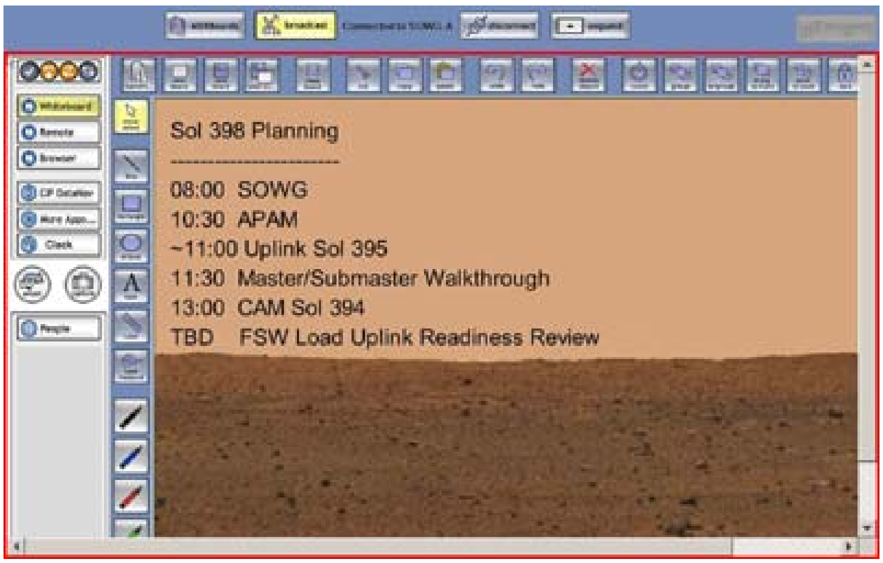

Figure 6-9. A schedule on the MERBoard whiteboard.

The visibility of the MERBoard was extremely important for the display of the sequencing schedules not only because it provided the shared awareness, but also because the schedule did not reside elsewhere, either physically or virtually. The tactical uplink lead emphasized this point by saying that the version of the schedule on the MERBoard served as the "official memory of the activity." If anything needed to change, he would announce it verbally and make the change official by editing the text schedule the MERBoard; thus the MERBoard was the only persistent source of schedule information for this team.

The flexibility and low overhead of using this tool was what made it successful for schedule authoring, editing, and display. The tactical uplink lead admitted that the reason he chose to use the whiteboard for this purpose was because he had never bothered to figure out how to use the CIP schedules that the scientists used. He could not afford to spend "8 hours learning how to do a task." The straightforwardness of the whiteboard tool for text entry and display made it the fitting choice for this task throughout the mission.

Suggestions for future design iterations: In keeping with the flexible and ad-hoc nature of the sequencing schedule maintenance, the team did not use any of the additional functionality available on the MERBoard for this task. Despite the "official" aspect of the schedules displayed on the MERBoard, the schedules were never saved. Instead, they were left open on the display and modified or replaced daily. When asked about this, the tactical uplink lead thought that it might have been a good idea to keep some record of past activities since the schedules were a fairly accurate reflection of how the activities actually occurred, but also pointed out that there had not been an actual need to revisit previous days' schedules thus far.

6.5.5 MERSpace User Directory

Although only mentioned explicitly by one scientist who worked on both the Spirit and Opportunity missions, the MERBoard Directory as a community awareness tool presents an unexpected and interesting potential use for the system. Although not originally intended for this purpose, one scientist used the photo icons in the MERSpace as a way of matching names to faces. Because the teams involved in the mission were made up not only of scientists and engineers resident at JPL but also from other institutes, this scientist often did not know a particular person with whom he needed to collaborate. He therefore employed the MERBoard as a way of looking up a name to find the face so he could find that person and start a face-to-face discussion, and even occasionally to figure out the name of someone whom he did not know. This user described this emergent use of the MERBoard as one of the most useful features of the system, and even referred to it as the “personnel section” of the system.

This user found it frustrating that only about half of the people in the directory had photographs associated with their accounts, and was frustrated that very little effort was made either by the users or by the teams to make sure that photos were added. He suggested that people might not have been sufficiently familiar with the process for adding a photo to their account, or not aware of the potential value of having a photo in the system, leading it to be a low priority for the users. This scientist described this as MERBoard’s greatest “missed opportunity,” not only for finding someone efficiently, but also for awareness. Nevertheless, he repeatedly returned to the directory on the off-chance that he could find someone when necessary.

This user did not make much use of the MERSpace on MERBoard for its original intentions. He did not author documents or use the directory as a way of emailing materials to others in the workgroup. He truly found the photographs to be the most useful feature of the MERSpace directory because he could easily look up someone’s email address in a database on his personal machine, but knew of no other way to access someone’s image. Despite the fact that this user was the only participant who explicitly mentioned this use of the MERBoard, it is an interesting and unexpected use of the system that may have benefited other members of the workgroups had they thought to use it as such or been more aware of the existence of that resource. This use of the MERBoard suggests its potential for supporting more general workgroup awareness outside of strict scientific tasks and activities. Given that many scientists in such missions may be collaborating with each other for the first time, MERBoard may have the potential offer social scaffolding in addition to the procedural scaffolding that tools such as SolTree offer. It is possible that the directory feature may be more beneficial for this purpose if it is made more immediately visible and more designed somewhat more explicitly as a community awareness tool; additional visibility might also encourage more users to attach images to their account if they find that the tool helps improve their own community awareness. Information such as that conveyed implicitly by this tool might be good candidates for additional passive display items.

Suggestions for future design iterations: This use of the MERBoard suggests its potential for supporting more general workgroup awareness outside of strict scientific tasks and activities. Given that many scientists in such missions may be collaborating with each other for the first time, MERBoard may have the potential offer social scaffolding in addition to the procedural scaffolding that tools such as SolTree offer. It is possible that the directory feature may be more beneficial for this purpose if it is made more immediately visible and more designed somewhat more explicitly as a community awareness tool; additional visibility might also encourage more users to attach images to their account if they find that the tool helps improve their own community awareness. Information such as that conveyed implicitly by this tool might be good candidates for additional passive display items.

6.6 Implications for Multi-Display Environment Design

In looking at the use of the NASA MERBoard over time, several patterns emerge across the various applications. These patterns demonstrate the evolving role of the system in the context of a dynamic work environment, and a complex ecology of displays. The evolution of the role of the MERBoard was clearly tied to several factors:

Changes in the collaboration style over time – MERBoard's value for collaboration was that it supported synchronous sharing of artifacts; multiple users could engage in viewing, authoring and discussing material simultaneously. The fact that procedures became familiar and routinized meant that responsibilities could be divided up among workgroup members and tackled individually, thus reducing the need for a shared work surface for synchronous collaboration.

Changes in the tasks of the scientists over time – MERBoard's value for interaction was primarily as a ramp-up tool that allowed users to conduct exploratory work, especially when procedures or tasks were unfamiliar, and scientists benefited most from doing them together to see and learn how the problems should be addressed. As the mission progressed and mission goals became more focused, tasks required less exploratory work and less time and effort for decision making; groups ceased to need the support for shared exploration and discussion afforded by MERBoard.

Other displays and applications available in the environment – MERBoards were one of many display technologies available to the scientists; the fact that they had other means of displaying information that also could be used for sharing, such as laptops and shared workstations for very small collaborations, and projection screens for large meetings, allowed tasks to migrate off of the MERBoard as necessary. Had MERBoard been the primary or only large display technology available to the scientists, the migration of tasks would have been different.

These three factors together shaped the use of the MERBoard during the mission and the pre-mission training. Taking these factors into account in evaluating the ebb and flow of

MERBoard use during the mission and pre-mission, we identified some implications for display ecologies and large interactive displays for supporting group work:

The transition from interactive use to ambient display – Designers of large displays should expect that the interactive use of large displays may not be constant over time, but that users may continue to find value in the ambient display capabilities of the systems. For this reason, applications and functionalities should not be designed only with interactive use in mind; attention should also be paid to how applications might be designed for passive use, what kinds of content might provide value while the displays are not being used interactively, and how that content can be easily shown on the display. In the case of the MERBoard, ambient use of the whiteboard for image display was valued, but not many users chose to post content. Low-overhead methods of information display might have helped to encourage this use, thus making the tool more valuable to the group. The Mars clock and schedule were both valuable to the group as ambient information; designers might also consider what other types of passive information would be of value for presentation in the environment.

The dynamic use of multi-display environments – Large interactive displays in multi-display environments are by nature group-owned and flexibly appropriable; constant, steady use need not be a goal that determines the success of such systems. Rather their value should be considered in terms of the ease and level of support for task and collaborations that benefit from the use of a shared interactive surface. Multi-display environments should therefore be designed to be flexible and dynamic, perhaps allowing them to be easily reconfigurable, and designing for the fluid migration of tasks among the various display surfaces.

Support for undefined tasks and proceduralization – Systems such as MERBoard support exploratory tasks and tasks that do not have a set procedure, becoming less necessary when work becomes streamlined and routinized over time. Designing for continuity by making data products easily accessible and movable between the various displays will help make transitions in work processes smoother, and help ensure that artifacts continue to be valuable as work progresses.

6.7 Implications for the Evaluation of Large Displays

From our in-depth study of the MERBoard within the context of a display ecology, we garnered several important lessons about evaluating the use of such systems. First, the "success" of a large interactive display within a display ecology cannot be measured by whether a steady state of use is reached. Because people appropriate these tools as necessary when tasks and collaborations require them, there may be a natural ebb and flow of use that does not correspond to success or failure, but rather to the dynamic nature of collaborative work processes. Success is therefore better evaluated by examining the ease and extent of support that such displays provide when tasks call for a shared visual display or interactive work surface.

Similarly, the notion of a "killer application" is one that needs to be reconceived in the context of shared displays in these environments. In the case of the MERBoard, because of changing tasks and collaboration styles, no application was used constantly throughout the mission. However, the SolTree clearly was a tool that got people to use the system, and functioned as a killer app in the sense that it was crucial to their work tasks for a period of time. During much of the time that the scientists were using SolTree for planning, planning methods such as the building of individual trees using PowerPoint would not have been sufficient because they needed the shared visual surface, as well as the shared exploration and decision making process. For these types of systems, killer apps may be better conceived as applications that support a particular task well enough to allow users to understand the value of the tool for the task.

Another important lesson regarding the value of large displays in work environments came from our observation of the interplay between interactive use and ambient information display. In the realm of large interactive display research, a decrease in interactivity is often viewed as a failure of the system to support workgroup practices. We observed a migration from interactive use to ambient information display, and through our interviews discovered how valuable this ambient information was. We therefore believe that success should be evaluated by looking both at interactivity as well as the value of the display in passive uses.

Finally, in the greater context of a display ecology, it is misleading to evaluate the isolated use of a single system; the existence of other displays in the environment means that it is important to understand how the ecology functions as a whole, not just how individual displays are used. Our findings lead us to suggest that the ebb and flow of use of a large display groupware system may not be an indication of problematic design or failure of the system to support collaboration sufficiently, but rather an indication that the need for such technologies in collaboration are dynamic rather than static. Just as researchers working together to write a paper may initially spend many hours brainstorming together using a whiteboard, the fact that they may later spend more time writing sections individually at their personal machines should not be regarded as a failing of the whiteboard to maintain collaboration; instead the nature of the collaboration changes, making other technologies more appropriate for the time being. In evaluating displays in such multi-display environments, we believe it is better to examine how well and fluidly the ecology as a whole supports the work tasks than to assume that disuse of a tool is a failure of the technology to support the task.

6.8 Reflections on Use and Adoption

This analysis of the MERBoard by functionality indicates that part of the perception of "low use" of the system may be because of low levels of explicit interaction with the display. While the MERBoard users did not make extensive use of the system for passive information display, the system was clearly holds potential for its combination of passive and interactive use. Even the tools designed primarily for synchronous collaboration, such as SolTree, provided value in its passive state. It may be worthwhile to consider how to allow users to migrate more fluidly between active and passive value, as well as to consider low-effort means of migrating content from laptops, repositories or other sources onto MERBoard for display. Additionally, it may be useful to consider the types of information that people found most valuable for persistent display, such as data products and schedules, and consider ways of making more of this type of content available without requiring explicit user interaction.

Evaluated within the context of a display ecology over an extended period of time, the NASA MERBoard can be considered somewhat successful in how it supported those tasks for which a shared work surface and shared visual display offered benefit. Its interactive and passive uses were important, and even crucial to the users at different points in the mission. The fact that it was used less for interactive purposes over time reflects the changing tasks and collaboration styles of the workgroup more than flawed design. MERBoard still presented several challenges to its users that decreased the overall flexibility and effectiveness of the display ecology as a whole. Users could not migrate content easily from SolTree into a form usable with a projector, creating additional overhead. Similarly, the work required to migrate content from a laptop onto the MERBoard may have decreased the use of MERBoard as an ambient display tool for sharing ideas and artifacts. The findings of our study and our design recommendations are currently being incorporated into new iterations of MERBoard's design that will be deployed at other NASA sites or to support future NASA missions.

CHAPTER 7

THE FIVE FACTORS REVISITED IN LIGHT OF THE MERBOARD EVALUATION

In order to understand the robustness, limitations, and explanatory power of the Five Factors Framework for large display groupware adoption, we have analyzed the adoption phenomena and use of many of the MERBoard's features as a way of reflecting upon the framework. We described most of the important adoption and use phenomena that we observed in the previous chapter; here we examine the correlations between our findings and the framework for the purposes of:

- understanding the value of the framework as an explanatory tool;
- further examining the potential value of the framework as a set of design guidelines; and
- refining the scope and limitations of the coverage of the framework.

The findings of this analysis of our data in reference to the Five Factors Framework leads us to five main categories of findings. We first identify examples of successful adoption of MERBoard's features that correlate positively to factors in the framework. We then identify adoption difficulties of certain features that correlate negatively with factors in the framework. Next we identify examples of mixed adoption success that agree with some factors and conflict with others. In light of these examples, we reflect on some of the factors in the framework that we believe need to be broadened in order to better account for some of the findings of this work. Finally, we discuss some of the issues that affected MERBoard adoption that we believe fall outside the scope of the design and deployment of LDGAs and therefore cannot be accounted for by the framework.

As we explained in Chapter 4 of this dissertation, the Five Factors Framework was developed based on the general findings of our evaluations across many LDGA systems. The factors in the framework do not necessarily describe phenomena that we observed in all systems, nor do we claim that adherence to the factors guarantees adoption success. Therefore, we do not analyze all of the MERBoard adoption successes and failures in light of all factors; rather we look at those that were most relevant and seemed to have the greatest bearing on the use of the applications, based on the data given to us by users and designers of the system.

7.1 Overview of Findings

In the tables below, we summarize the use and adoption phenomena, organized by the factors of their application design and deployment that played a role in their use, according to our data. The following table (Table 7-1) shows positive examples of adoption that correlate to adherence to the factors:

Table 7-1. Positive examples of adoption that correlate to the factors

Design/Deployment Factor	Examples of its role in MERBoard adoption
Task specificity and integration	SolTree quickly adopted by scientists
Tool flexibility and generality	Whiteboard used for schedule display and authoring by engineers
Visibility and exposure to others' interactions	SolTrees left open for group awareness Passive images displayed on whiteboard
Low barriers to use	Whiteboard used for schedule display and authoring by engineers Clock becomes default content for ambient display
Dedicated core of users	SolTree quickly adopted by scientists Passive images displayed and used on whiteboard Whiteboard used for schedule display and authoring by engineers

Table 7-2 below shows examples of applications falling into disuse or underuse in relation to a conflict with a factor:

Table 7.2: Examples of adoption difficulties in relation to the factors

Design/Deployment Factor	Examples of its role in MERBoard adoption
Task specificity and integration	Whiteboard not frequently used by scientists
Tool flexibility and generality	SolTree replaced by PowerPoint as planning becomes proceduralized later in mission
Visibility and exposure to others' interactions	MERSpace directory not widely used for identifying colleagues Unclear when clock was not being used
Low barriers to use	Whiteboard not frequently used for collaboration because of overhead for displaying content MERBoard slaving feature too complicated for presentations SolTree replaced with personal laptops for planning late in mission CIP schedules not used by engineers
Dedicated core of users	MERSpace directory not widely used for identifying colleagues

The table above shows infrequent use or a lack of use of certain MERBoard features for various tasks, but it should also be noted that this table is inherently incomplete because of the nature of this analysis. For example, we cannot say with any certainty that the lack of a dedicated core of users led to the underuse of the whiteboard for sketching and authoring; our participants did not suggest that they didn't use the whiteboard because they were not encouraged to do so by their colleagues. However, that is not to say that a dedicated core of users would not have helped promote whiteboard adoption; given our findings from this and previous studies about the influence of champion users, it is in fact fairly likely that champion users would have had a positive impact on the use of the whiteboard tool as well. The table we present here reflects instead the direct connections between factors and disuse uncovered by our study; it is not intended to suggest that adherence to other factors would not have had an effect on the use of the features. For example, we state that the use of the MERSpace user directory as a means of identifying colleagues suffered from not having enough dedicated users to populate the directory sufficiently, according to the single user who reported trying to use it for this purpose.

The high-level results of this analysis are reflected in the two previous tables; we now explore some of the uses of the MERBoard in greater depth, examining the interplay among the multiple factors that affected their use. Many of the phenomena we observed in the use and adoption of the MERBoard are in keeping with the findings of our previous studies and can be accounted for through the framework factors. Several positive instances of tool adoption correlate well with factors we identified in design and deployment. Similarly, several negative examples of adoption and use can also be traced to design and deployment that is not in keeping with the factors. Finally, the MERBoard also displayed examples of mixed adoption success, which can be related to mixed adherence to factors, or tensions between factors. In this section, we present some examples of positive, negative, and mixed feature adoption, and describe the role that the factors played in their respective uptake. We analyze each of the features according to the specific uses for which they were intended, or for which they were used.

7.2 Examples of Positive Adoption Based on Factors

The clearest adoption success for the MERBoard was the use of the SolTree tool for Sol planning in the first 70 Sols of the nominal mission, as described in the previous chapter. The success of this tool for this use can be related to adherence with two of the factors: a dedicated core of users, and task specificity and integration. Although the use of SolTree was not mandated, key individuals in the Long Term Planning (LTP) theme group, such as the LTP leads and LTP documentarian championed the use of the tool and used it consistently to maintain continuity between the rotating groups of LTP scientists involved in the Sol planning. Although SolTree was generally received enthusiastically by LTP scientists in the early part of the mission, a few scientists expressed dissatisfaction with the design of the tool, objecting to the rigidity of it. Even so, these scientists used it because the LTP leads used it and it was the accepted manner of conducting planning. While the design of the tool may not have been ideal for all users, champions of the system encouraged its use leading to its successful adoption. The integration of the tool into a necessary and important scientific task also helped to contribute to its success. The tool was not only designed and deployed to support the mission-critical Sol planning task, the fact that it was available on a large, shared display helped make it superior to any desktop tools that the scientists might have otherwise used. The tree-building tool fit well with the technical aspects of the tasks, and the shared visual work surface fit well with the fact that this task needed to be done synchronously and collaboratively in the early months of the mission.

Another positive example of feature adoption was the use of the whiteboard for creating and displaying schedules for the sequencing engineers. The tactical uplink lead engineer who determined the schedule of events for the day attributed the use of the whiteboard primarily to the low barriers to use. He compared the tool to the CIP portal that most other groups used for displaying and maintaining schedules, stating that he preferred the whiteboard because it did not require him to learn anything new to use it, and that he did not need to do anything other than type in order to input or edit a schedule. We can therefore also attribute the success of this application for this task to the flexibility and generality of the tool, as it did not impose any structure on the task or the actions necessary to accomplish it. The engineer also explained that the visibility of the schedule on the MERBoard led to its use as the master copy of the schedule; although schedule information was sometimes conveyed via word of mouth or email, it was generally accepted that the schedule on the MERBoard was the most up-to-date and accurate version, and that events and changes were made definite when they were reflected on the board. The MERBoard copy was accepted as the "master copy" of the schedule to the extent that members of other engineering groups sometimes visited the space to check or confirm scheduled events on the display. The visibility of interactions with the board, namely the results of the tactical uplink lead's schedule authoring and editing, led to awareness of the tool and its value, and caused it to be adopted as the primary schedule information source for the members of this group.

7.3 Examples of Adoption Difficulties Based on Factors

In addition to positive adoption instances of MERBoard features, we also observed examples of poor adoption of certain features for tasks that can be attributed in large part to design or deployment issues that were in direct conflict with one or more of the factor of our framework. For example, several scientists expressed that they were disappointed with the lack of use of the whiteboard application for sketching or the collaborative authoring or annotating of artifacts. They stated that they rarely used the whiteboard for such tasks and that their use of it dropped over the course of the mission. As described in the previous chapter, the decrease in whiteboard use over time is likely due in part to the changing nature of collaboration over time and a decreasing need for synchronous collaboration on a shared visual surface. The general lack of uptake of this tool for these purposes can still be related to some of the factors.

In particular, scientists expressed a frustration with the overhead necessary to migrate information to the whiteboard from their laptops or workstations. In comparison to the use of conventional projection, which only required users to plug their laptops into the projector, the scientists found that the MERBoard interactions necessary to display artifacts that they had created on their laptops to be a major deterrent to use. The use barriers were too high to warrant the use of this tool when there were satisfactory workarounds available; the benefits of MERBoards capabilities for annotation and editing generally did not outweigh the ease of use of projectors for collaboration. Additionally, the tool was designed to be quite flexible and general, but was not deployed to support any specific and necessary tasks; this may have contributed to the fact that scientists did not identify any regular uses for the task. Unlike the use of the whiteboard for the sequencing engineers' schedules and the LTP scientists' use of SolTree for planning, there were no collaborative uses recommended for this tool by influential group members. Without initial specific tasks to get users to begin interacting with the whiteboard, the tool was underused, and perceived as not providing much value or support. Because it was designed to be so flexible and general, but not deployed to support any particular tasks, it did not suggest any particular uses.

The use of the MERSpace user directory as a way of identifying unknown colleagues is an interesting example of a failure of adoption because it was not an intended use of the MERBoard, and the MERBoard was therefore not designed to support it. It was, however, an interesting and potentially valuable use of the system identified and used by at least one scientist. This scientist found, however, that the application broke down for the purposes of identifying colleagues because only about half of the group members had photographs of themselves associated with their directories. We can likely attribute this failure in part to a lack of visibility regarding the tool. Because the user directory was not highly visible as content on the MERBoard, other users may not thought to have used it as a way of identifying colleagues. Additionally, users may have deemed it unimportant to add their pictures to their MERSpace account or not even known that they could associate a picture with their personal repository because they were not aware that anyone was using it to try to identify them. Not only was the functionality insufficiently visible for this use, but the group members had no way of knowing that this user was interacting with the MERSpace directory as such. Other users were therefore not aware that anyone else was using the tool in this manner, or that they too could use the tool for this purpose.

7.4 Examples of Mixed-Success Adoption Based on Factors

One example of the use of a tool for a task that met with mixed success is the use of the whiteboard feature for passive image display. As explained in the previous chapter, the use of the MERBoard for passive image display was reasonably successful in the Spirit mission because one user in particular frequently posted annotated images of interest for his colleagues to see, use, and discuss. The success of this tool for this task is mixed because while only one user was cited as regularly posting images, many of the scientists spoke of using the images that he posted, making active use of them by discussing them, revisiting them. They also noted the value of the images for increasing their awareness of the data and interpretations of the data. While the tool was not widely adopted by many as a means of posting and sharing images, it was successful in that it was regarded as valuable and the content was used and appreciated.

The mixed success of this use of the whiteboard can be attributed to the factors as well. As described in the section on the infrequent use of the whiteboard by the scientists for collaborative tasks, many scientists found that sharing artifacts on the whiteboard required too much interactional overhead. In speaking to the Geology scientist who frequently posted images, however, we found that he considered the barriers to use to be lower than those for displaying an image on a projector because the use of the projector required the physical action of interacting with cables and ports and monopolized his laptop; for his goal of putting information into the environment for others to use, giving up his laptop so that it could be used to project information was an enormous barrier to use. This scientist also suggested that the barriers to use were a matter of perception and visibility; because the interaction required to display an image was not as visible on the

MERBoard as it was on the projector, potential users may have perceived the interactional overhead as being greater than it actually was; the high barriers to use may not have been merely interactional, but cognitive as well because it required users to figure out how to display the image. The act of sharing information with others in this ambient, non-urgent manner was appreciated by the other scientists, but not believed to be a critical or necessary task. Scientists did not perceive a need to share information in this way, even though they found it interesting and informative to look at the images posted by the Geology scientist. The fact that this use of the tool was not necessary led to little use for this purpose; scientists were generally too busy with other more pressing tasks. The scientists perceived a high barrier to use, but also perceived the system to be valuable and interesting to their work because of the visible actions of a champion user. This visibility and the existence of a dedicated user led the tool to be used as a source of information by many, but the fact that it was supporting a task that was deemed superfluous overall and the fact that it was perceived as having high barriers to use prevented it from being more widely adopted as a way of conveying information.

As we can see by the results described above, there are variations in which factors are important for which features, and that not all factors are important for all features. For example, the SolTree tool was designed to provide fairly rigid support for Sol planning, and thus did not adhere to the guideline of generality and flexibility. It was, however, unquestionably successfully adopted for the early months of planning on account of its integration into a necessary task and its dedicated core group of users. On a similar note, we can see that tensions between various factors could lead to mixed success; the passive image display on the whiteboard had a champion user, but high overhead for posting. As a result, it was successful for display, but not well adopted for posting information. Our findings show that the factors and the adoption success are related, though adherence to the factors is not necessarily a guarantor of success.

7.5 Broadening the Factors in the Framework

Based on the findings described above, we believe that some of the factors in the framework require some broadening to truly reflect these findings. In particular, the notion of visibility of others' interactions must be widened to include not only making visible that others are using the LDGA, but also what they are using and how they are using it. For example, in the case of the scientist who used the MERSpace directory as a way of identifying colleagues, it was not only visible to other users that he was doing so, but the functionality itself was not sufficiently visible for others to understand this potential use of the system. In the example of visibility that we presented in Chapter 4, users discovered the email feature of the Plasma Poster by receiving these emails themselves. In this case, however, the functionality was sufficiently visible and explicit on the interface that other users were easily able to figure out how the interaction occurred. For the MERBoard MERSpace directory to become similarly valuable, it would be important not only to make other users aware of when others were using it, but also to make the interactions themselves more apparent to users so they could duplicate them themselves.

Of particular interest was the Mars clock that comprised the majority of MERBoard use in the later months of the mission. The clock presented an interesting analytic challenge because it was not only adopted, it seemed to fall into an "over-adoption" rut. Some of the scientists believed that the use of the clock may have prevented the use of other applications on the MERBoard. Furthermore, some scientists suggested that the clock superceded the use of other MERBoard tools not because the scientists needed the clock at all times, but because they could not tell if others needed it and were therefore hesitant to deprive others of it by using the MERBoard for another purpose. This phenomenon was generally regarded as detrimental to the use and value of the MERBoard.

The design and deployment of the clock adhered strongly to some of the factors. It had very low barriers to use, requiring almost no interaction to access the information except to look at it; like a conventional clock, it was located in the environment and therefore did not consume desktop screen real estate. Additionally, it was an extremely general tool; it did not lend itself to specific tasks, and displayed information that was general in and of itself, and of broad relevance to the group as a whole, not just specific members. While the clock was successful in part because it was so highly visible, one of the reasons for its over-adoption was that people's use of the display was not visible. Because of its ambient and passive nature, people who wanted to appropriate the MERBoard for interactive use could not determine if others were currently using the clock, and this proved to be a barrier to use for the other functionalities. From this example, we can conclude that adherence to the design recommendations offered in the Five Factors Framework can possibly cause over-adoption in the sense that other potential uses may be compromised by a well-adopted tool. It is possible that the use of another factor, in this case making users' interactions visible, might have helped to prevent this over-adoption rut; if the application had some way of determining and reflecting whether people needed it, that may have helped balance the use of the MERBoard functionalities.

In our original formulation of the framework, we treated task specificity and integration as an issue of deployment and tool flexibility and generality as an issue of design. In general, we found that this combination continued to yield success in the case of the MERBoard, applications that were deployed for specific, necessary tasks and integrated into important activities were well-adopted, while some of the more general tools such as the whiteboard met with difficulty when the users did not hit upon good uses for them on their own. At the same time, however, we found that one of the major strengths of the SolTree tool especially at the beginning of mission was that it was not designed as a general, all-purpose tool, but rather as specific support for a task. This tool was not only deployed for a specific task, but designed for one as well. As the mission progressed, users replaced SolTree on the MERBoard with the transitional use of the whiteboard on the MERBoard because the whiteboard provided more flexibility. This suggests to us that the factor of generality and flexibility in design should have a greater emphasis on flexibility, as there is clearly potential value for tools that are general in design as well as those that are specific. Our interviews with scientists suggest that greater flexibility in SolTree might have encouraged them to use it for longer rather than switching to using the whiteboard, and eventually to PowerPoint. Although SolTree's structure was valuable at the beginning, flexibility in the level of support might have lengthened the use of the tool.

7.6 Findings Outside the Scope of the Framework

By investigating the challenges and adoption successes of MERBoard's features for various tasks, we confirmed that the design and deployment factors in our framework correlated strongly with the scientists' accounts of why they did or did not use the tools that MERBoard provided. While these findings support the value of the factors in the design and deployment of large display groupware systems, it should be noted that they do not verify the completeness of the framework, nor was the study intended to validate the framework for completeness. As described in Chapter 4, the framework was developed by looking at adoption phenomena that were common across many of the systems that we examined, but not necessarily all. Additionally, as the framework provides design and deployment guidelines rather than conditions that must hold, this in-depth evaluation of the MERBoard does not prove adhering to all five factors guarantees adoption, nor must a design adhere to all the factors to be successful. Rather, what we learn about the framework from studying the connections between the factors and the MERBoard is that in this in-depth study of a large display groupware system, as in our briefer exploration of other large display systems, the factors play an important role in the use and adoption of the system's features. The results of our evaluation of the MERBoard support our belief that the five factors are important to consider when designing and deploying large display groupware systems.

Although our in-depth study of the MERBoard and previous explorations of other large display groupware systems point to the relevance of the Five Factors Framework for adoption, the framework is not intended to explain all adoption and use phenomena. In our study, we uncovered several major challenges to use and adoption that are not accounted for by the framework, some of which we did not observe in our studies of other systems.

The evolution of the use of some MERBoard features over time can also be traced to the changing nature of collaboration and the changing tasks over the course of the mission. In the previous chapter, we described how increasing proceduralization of planning tasks and the simplification of planning decisions caused use of SolTree on the MERBoard to give way to PowerPoint on desktop machines. Users needed a rigid structure and shared visual surface when they were first collaborating, but required flexibility and the ability to work independently later in the mission. It is possible that tools like SolTree could be designed to provide different levels of support of support as needed, but it seems unlikely (and perhaps undesirable) that such tools could be designed in such a way that the users would continue collaborating synchronously on the shared display when the task no longer required it. In this case, the task changed from one in which the use of a shared visual surface for collaboration offered benefit to one in which it was more efficient and effective to use personal displays and work independently. This is a case of an adopted tool falling into disuse for reasons external to tool design and deployment, and underlines the basic limitation of the framework as a design tool that we stated in chapter 4: design and deployment decisions in adherence with the framework will not lead to adoption and use of the tool if it does not address a task that users want to do. In this case, the task that MERBoard supported evolved into a task for which a large shared display offered little or no benefit.

The physical limitations of the MERBoard presented additional hurdles to adoption and use that could not be easily solved with application design and deployment tactics. An engineer that we spoke with found the visual parallax on the screen irritating; he described the interaction with the touchscreen as being “not quite right” as a result of it. This same engineer stated that he had attempted to use the MERBoard once or twice for the purpose of giving presentations and “scribbling” but he found the touchscreen so difficult to use that he used projection for future presentations. In his case, the benefit of being able to annotate displayed content was outweighed by the awkwardness of the touchscreen. This same user also found the experience of writing and scribbling on the board uncomfortable, saying that using the whiteboard on MERBoard effectively necessitated “learn[ing] how to write all over again… feels like drawing with a crayon.” He felt that the MERBoard’s resolution and pen tools made him unable to use fine motor control and required him to use big gestures to write or draw. This user instead used the keyboard as a way of inputting text on the MERBoard; this allowed him to take advantage of MERBoard’s group visibility while avoiding having to write on the surface. Another scientist expressed a similar reaction to the parallax and the touchscreen, stating that using the touchscreen was “not difficult, but not easy.” This user was optimistic about the potential for the display, saying that he believed people would get used to the parallax and adjustment in writing if they used it enough.

The size and resolution of the MERBoard also created some limitations that would not be easily solved through design and deployment. MERBoard’s physical size fits an interesting niche, demonstrating that not all large displays are created equal where size is concerned. Scientists repeatedly said that for large meetings such as the end-of-Sol meetings or SOWG meetings that projecting content onto a screen was superior to using MERBoard because MERBoard was too small and was neither sufficiently visible nor readable from a distance. Text was especially problematic because the ratio of the size of text created on MERBoard to the size of the display was much smaller than the ratio of, say, projected text in a PowerPoint slide to the size of the projection screen. For collaborating around images, some scientists preferred to use large printouts of terrain data or PanCam images oriented horizontally on a table. In addition to fostering collaborative annotation, which was done using conventional magic markers, the images provided considerably more detail because they were higher resolution. Additionally, scientists were comfortable with printouts because they had used them in previous research or missions.

For small collaborations, some scientists found that the size of MERBoard was more than necessary, given the overhead required to put content on the MERBoard for a collaborative activity. Two or three people working together could easily crowd around an SAP terminal or laptop, and these small screens were found to be brighter and higher resolution than MERBoard by the scientists. MERBoard, being an intermediate size between an SAP display and a projection, therefore seems best suited to mid-size collaborations of perhaps between four and a dozen or so people. While it is the case that most of MERBoard's interactive use (especially for SolTree) involved groups of about this size, it is also the case that when collaborations grew past the size appropriate for crowding around a laptop, they generally migrated to a projected screen rather than to MERBoard.

An additional unexpected challenge arose from the tension between the MERBoard as an authoring tool and the MERBoard as a display device. The SolTree tool shows this contrast particularly strongly. SolTree was designed primarily as a tool for interactive authoring of Sol plans, a task that it supported well. When scientists tried to use it as the display for showing the plans at larger meetings, it was unsuccessful because the absolute size of the screen was too small for viewing by such a large group, and also because the visualization of the SolTree contained too much detail at too small a size to be visible. One of the scientists said that when the SolTree was displayed at a large meeting, the person presenting the tree would talk through it and he would “take his word for it” because he could not actually see the details. Many scientists also said that the level of detail necessary in the visualization during the planning was more than necessary when presenting the SolTree, and that the additional detail made for clutter. As a result, MERBoard was eventually abandoned as a tool for displaying SolTrees at meetings, although it continued to be used as an authoring tool for some time. Although the scientists continued using SolTree, they did complain of the need to transcribe SolTrees into simplified plans in PowerPoint for use in presentations. Some additional flexibility in the design of SolTree might have helped it to bridge the gap between an interactive surface and a display tool; one scientist suggested the ability to display plans with varying levels of detail shown or hidden. This might not have solved the problem of the SolTrees being viewable from a distance during a large group meeting, but simpler ways of migrating the content either into PowerPoint or onto a projector might have helped as well.

Overall, the Five Factors Framework served as a valuable tool for understanding and classifying many of the major issues surrounding the adoption of the NASA MERBoard. As would be expected with a generalized framework, the MERBoard faced some adoption challenges that fell outside of the scope of design and deployment covered by the MERBoard. Using the MERBoard evaluation as a primary in-depth case study for iterating upon the framework, we have identified some factors that need to be broadened to account for the findings of the evaluation more accurately. In light of these modifications, the framework accounts well the majority of adoption and use phenomenon that we observed in the use of the MERBoard applications.

CHAPTER 8

CONCLUSIONS AND FUTURE WORK

In this dissertation, we have described our findings based on our research in designing, deploying, and evaluating large display groupware applications. We have also applied our findings to the creation of the Five Factors Framework for the adoption of large display groupware. In this final chapter, we summarize the key points of this research and present some concluding remarks and future directions for this work.

8.1 Summary of Findings

We believe that this work offers several key findings that further the state of research in the field of large display groupware applications. In particular, we believe that our work has shown that:

- LDGAs designed to provide support for existing workgroup communication, collaboration, and information awareness practices help to improve or augment these practices, by providing an additional channel for information display or interaction that are better suited to the activities in some circumstances.
- Adoption and integration into everyday work practices is a real challenge for LDGAs and by studying adoption across a large set of LDGAs, we have identified several factors of design and deployment that are tied to adoption success.
- Our framework of adoption factors can be used as a set of design guidelines that can have a positive impact on the adoption of novel LDGAs.

- Our framework can be used to explain many of the adoption phenomena surrounding an LDGA within a display ecology though there may also be issues apart from design and deployment that may affection adoption and are not covered by our framework.
- Evaluating an LDGA within a display ecology offers unique perspectives regarding the use and success of the application. It is important to consider how the ecology as a whole supports user needs, including how flexibly tasks and content can be migrated to and from the large display as the users and activity require.

8.2 Future Directions

We believe that one of the strengths of this work stems from our findings being gathered from studies of many systems, especially those that had been designed and deployed by others. We believe this perspective offers additional robustness and validity to the general findings of this research.

8.2.1 An Exploration of Multi-Display Environments

In exploring the future directions for this work, we aim to continue broad studies of multiple systems to offer findings and contributions to the community that can be used and applied by other researchers in design and evaluation. Specifically, we aim to continue shifting the focus of this work from understand large displays to understanding display ecologies by examining multi-display environments that may also contain large displays.

Although several multi-display systems have been built and researched [Carter *et al*. 2004, Voida *et al*. 2002, Streitz *et al*. 1999, Johanson *et al*. 2002], these projects are primarily composed of devices or displays designed explicitly to work together to form a single system. We aim to look more broadly at multi-display environments and include those like the MER environment in which multiple display technologies may be used in conjunction to support tasks and activities, but for which the technologies may not have been specifically designed to form a single, coherent system. Our findings from the MERBoard study suggest to us that even when technologies are not designed to work together, they can still form a display ecology that can provide flexible support for workgroups. Furthermore, the differences in affordances and applications available on the displays may even have contributed to the flexibility of support.

We believe that the next direction for this work is to consider multi-display environments broadly by looking across several environments in deployment and use to understand how ecologies form and what makes them successful. Multi-display environments are beginning to emerge as the technology required for them becomes more affordable and available. Despite the increasing feasibility of such systems from a hardware and networking perspective, little is still known about how best to design the interactions and software necessary to make such systems successful and useful in general. In continuing this research, we intend to take initial steps towards gaining generalized knowledge about how these systems can be designed and deployed by examining a broad range of multi-display environments in a variety of domains and in authentic use settings. We believe this investigation will facilitate the formalization of findings and recommendations that will be applicable to the design of future multi-display environments. In particular, we are interested in discovering on a generalizable level:

- ***What do people do with multi-display environments?*** What are the various collaboration and coordination styles that people adopt when using technologies in multi-display environments? How do the properties and affordances of the technologies influence these interactions, and how do the collaboration and coordination styles in turn affect the use of the technologies?
- ***How do multi-display environments vary by domain and users?*** How do the coordination styles and uses of these technologies vary across different user populations and domains? For example, how is the appropriation and social coordination of a display system for museum visitors different from that of a system intended for long-term collaboration within an office environment? What aspects of their use and interaction are common between them?
- ***How do multi-display environments vary due to differing display ecologies?*** What are the key characteristics that distinguish different types of multi-display environments from one another? In particular, how are their uses and adoption affected by differing notions of ownership, intended duration of use, content types, and types of user populations?

By addressing these key research questions, we aim to provide the following as findings to the research community:

- An understanding of overall patterns among multi-display environments, including accounts of recurring phenomena among such environments, and an enumeration of some of the critical dimensions along which they vary

- A taxonomy of types of multi-display environments meaningfully categorized along the aforementioned dimensions, including findings about the best uses and limitations or challenges of each type
- A set of design recommendations for multi-display environments based on our findings of the successes and challenges of these environments, including high-level guidelines for multi-display environments in general, as well as more specific recommendations for supporting different types of domains, user populations, or intended purposes.

To achieve this we aim to conduct in-depth, qualitative studies of several multi-display environments, supplemented with observations of additional available sites when possible. To broaden the focus beyond work environments, we may consider collecting data from a broad range of domains, including business, academia, and research, as well as more publicly available systems, such as those found in museums and train stations.

Future possible steps stemming from this work may include the development of novel systems with the assistance of design guidelines resulting from this study, and design iterations of existing multi-display environments based on the findings of this work. Our work in understanding and designing for large display groupware applications provides a strong basis for continuing the research in the direction of understanding display ecologies.

8.2.2 Encouraging User-Submitted Content

Another possible future direction for this work relates to some of our findings from our early explorations into the space of information awareness applications.

Especially as pertains to low use barriers for LDGAs, we believe that one of the major challenges for awareness applications on large displays is obtaining enough user-submitted content to create a perception of use and value within a workgroup. In our design of Semi-Public Displays, we addressed this issue by relying as much as possible on existing information as content. However, as shown by our work on the Awareness Module as well as the use of the NASA MERBoard for passive image display, some users clearly would like to use these channels as tools for information dissemination, and others find value in viewing this information in the work environment.

We believe there is value in investigating what users find rewarding about posting or receiving information, and finding ways to make the displays and visualizations more reflective of these benefits, to encourage additional participation and the perception of value. Positive metrics of interest or viewership such as those often used on news websites or online photo albums may have even more value for these types of applications since they are highly visible and used by workgroups rather than collections of individuals. Exploring the possible ways of not only lowering use barriers but also encouraging active submission of user content for awareness applications is a valuable next step in this work.

8.2.3 Exploring LDGA Identity

Another possible direction of this work is to explore how LDGAs develop identities and how these identities might be supported through design. For example, within the MER science assessment rooms, MERBoards developed identities through ownership and location; each science theme group had its own MERBoard, and its use was determined by who owned it. For example, the Long-Term Planning group used their board primarily for SolTree, whereas the "unowned" MERBoard in the front of the room was primarily for display during meetings. The display that we used for IM Here had a more explicit notion of identity; in addition to being strongly affiliated with a particular physical location, the board had its own IM screen name and was thus identifiable during IM conversations. In contrast to LDGAs, desktop machines and personal displays tend to have a stronger sense of identity because they are typically owned by a single user and rarely used by others, if ever. One potential future path of research is to understand how a sense of identity, be it explicit or implicit, affects how users perceive and adopt LDGAs, and how it contributes to a sense of ownership. Additionally, it would be of interest to explore what characteristics or uses contribute to a sense of LDGA identity and whether identity can be beneficial to users' perception of the value of the applications.

8.3 Conclusions

This dissertation examines in depth some of the challenges for the rapidly emerging area of large display groupware from the perspectives of design, deployment, and evaluation. Our work adds to a growing body of knowledge about how to design these applications to be valuable and successful, alongside complementary research addressing interaction design, perception, and hardware design. Additionally, this research contributes to the community's growing understanding of the role of large displays in work environments and their potential for supporting group work practices.

Although the question of how best to design large display groupware remains open, and is unlikely to be entirely addressed by any single, general solution, the work we have put forth here makes inroads by addressing important issues regarding their use and value in real settings. By exploring the issues of adoption, evolution of use over time, situatedness, the display ecology, and the influence of other aspects of the work environment, we contribute to a deeper understanding of the meaning for these technologies within the context of human activity, and with a human-centric perspective.

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VITA

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